US011208029B2

(12) **United States Patent**
Spero

(10) **Patent No.: US 11,208,029 B2**
(45) **Date of Patent: Dec. 28, 2021**

(54) **ADAPTIVE HEADLIGHT SYSTEM**

(71) Applicant: **Yechezkal Evan Spero**, Tifrach (IL)

(72) Inventor: **Yechezkal Evan Spero**, Tifrach (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/152,399**

(22) Filed: **Jan. 19, 2021**

(65) **Prior Publication Data**

US 2021/0162912 A1 Jun. 3, 2021

Related U.S. Application Data

(63) Continuation of application No. 15/961,861, filed on Apr. 24, 2018, now Pat. No. 10,894,503, which is a (Continued)

(51) **Int. Cl.**
B60Q 1/04 (2006.01)
F21K 9/23 (2016.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B60Q 1/04*** (2013.01); ***B60Q 1/085*** (2013.01); ***B60Q 1/1423*** (2013.01); ***F21K 9/23*** (2016.08); ***F21K 9/232*** (2016.08); ***F21S 4/28*** (2016.01); ***F21S 41/143*** (2018.01); ***F21S 41/147*** (2018.01); ***F21S 41/153*** (2018.01); ***F21S 41/65*** (2018.01); ***F21V 19/02*** (2013.01); ***F21V 23/0464*** (2013.01); ***F21V 23/0471*** (2013.01); ***F21V 23/0478*** (2013.01); ***H05B 3/008*** (2013.01); ***H05B 45/20*** (2020.01); ***H05B 45/395*** (2020.01); ***H05B 47/10*** (2020.01); ***H05B 47/105*** (2020.01); ***H05B 47/11*** (2020.01); ***H05B 47/115*** (2020.01); *B60Q 2300/054* (2013.01); *B60Q 2300/112* (2013.01); *B60Q 2300/116* (2013.01); *B60Q 2300/122* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B60Q 1/04; B60Q 1/085; B60Q 1/1423; B60Q 2300/112; B60Q 2300/134
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,316,442 A 4/1967 Konrad
4,597,033 A 6/1986 Meggs et al.
(Continued)

FOREIGN PATENT DOCUMENTS

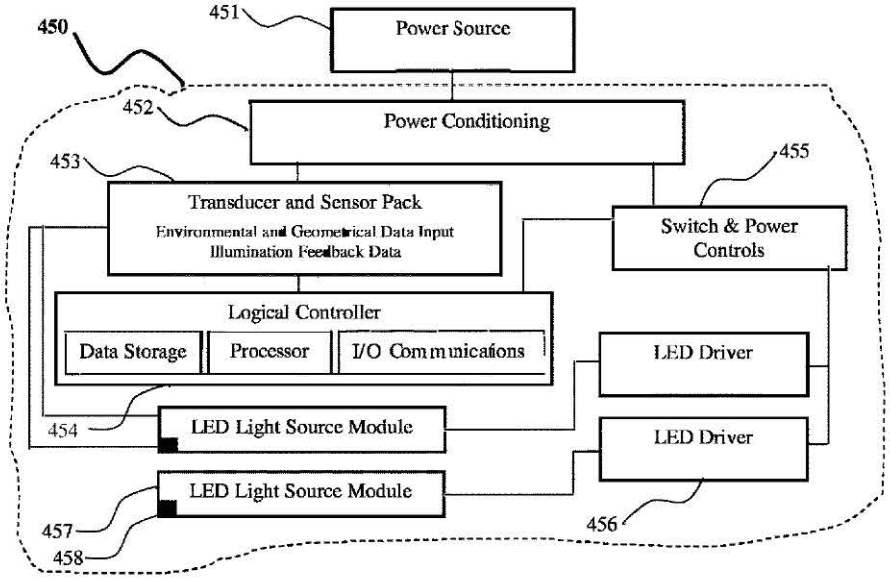
WO 2001070538 A2 9/2001

Primary Examiner — Tung X Le
(74) *Attorney, Agent, or Firm* — Brooks Kushman P.C.

(57) **ABSTRACT**

A motor vehicle includes headlamps having a plurality of LED light sources, one or more processors, and a memory storing instructions. One or more processors executing the instructions are enabled to receive first data, including at least map data, indicating a road curvature upcoming along a road on which the motor vehicle is traveling. The processors are also enabled to determine a light change, the change adapting a light pattern of the headlamps in at least one of color, intensity or spatial distribution to increase light in a direction of the road curvature ahead of the motor vehicle and shaping light based at least in part on the road curvature. The processors are further enabled to control at least a first plurality of the LED light sources to provide light based at least in part on the determined light change and prior to the motor vehicle reaching the road curvature.

33 Claims, 24 Drawing Sheets



PCNA Ex. 1001
U.S. Patent 11,208,029

Related U.S. Application Data

continuation of application No. 13/357,549, filed on Jan. 24, 2012, now Pat. No. 9,955,551, which is a continuation-in-part of application No. 10/604,360, filed on Jul. 14, 2003, now Pat. No. 8,100,552.

(60) Provisional application No. 60/395,308, filed on Jul. 12, 2002, provisional application No. 61/535,981, filed on Sep. 17, 2011.

(51) **Int. Cl.**

F21K 9/232	(2016.01)
B60Q 1/08	(2006.01)
B60Q 1/14	(2006.01)
F21V 19/02	(2006.01)
F21V 23/04	(2006.01)
F21S 4/28	(2016.01)
F21S 41/143	(2018.01)
F21S 41/147	(2018.01)
F21S 41/65	(2018.01)
H05B 47/105	(2020.01)
H05B 45/20	(2020.01)
H05B 47/10	(2020.01)
H05B 47/11	(2020.01)
F21S 41/153	(2018.01)
H05B 47/115	(2020.01)
H05B 45/395	(2020.01)
H05B 3/00	(2006.01)
F21V 29/74	(2015.01)
F21Y 115/10	(2016.01)
F21V 21/02	(2006.01)
F21V 21/30	(2006.01)
F21W 111/023	(2006.01)
F21W 111/027	(2006.01)
F21W 111/08	(2006.01)
F21W 131/103	(2006.01)
F21W 131/40	(2006.01)
F21Y 113/00	(2016.01)
F21W 102/00	(2018.01)

(52) **U.S. Cl.**

CPC .. *B60Q 2300/134* (2013.01); *B60Q 2300/142* (2013.01); *B60Q 2300/21* (2013.01); *B60Q 2300/23* (2013.01); *B60Q 2300/312* (2013.01); *B60Q 2300/314* (2013.01); *B60Q 2300/322* (2013.01); *B60Q 2300/41* (2013.01); *B60Q 2300/42* (2013.01); *F21V 21/02* (2013.01); *F21V 21/30* (2013.01); *F21V 29/74* (2015.01); *F21W 2102/00* (2018.01); *F21W 2111/023* (2013.01); *F21W 2111/027* (2013.01); *F21W 2111/08* (2013.01); *F21W 2131/103* (2013.01); *F21W 2131/40* (2013.01); *F21Y 2113/00* (2013.01); *F21Y 2115/10* (2016.08); *Y02B 20/30* (2013.01); *Y02B 20/40* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,018,290	A		5/1991	Kozek et al.
5,033,099	A		7/1991	Yamada et al.
5,130,909	A		7/1992	Gross
5,546,475	A		8/1996	Bolle et al.
5,561,346	A		10/1996	Byrne
5,577,832	A		11/1996	Lodhie
5,749,646	A		5/1998	Brittell
5,785,243	A		7/1998	Cross
5,796,094	A	*	8/1998	Schofield B60N 2/002 250/208.1
5,803,579	A		9/1998	Turnbull
5,921,660	A		7/1999	Yu
5,969,754	A		10/1999	Zeman
5,983,161	A		11/1999	Lemelson et al.
5,994,844	A		11/1999	Crawford et al.
6,046,549	A		4/2000	James
6,049,171	A	*	4/2000	Stam B60Q 1/1423 315/82
6,149,283	A		11/2000	Conway et al.
6,166,496	A		12/2000	Lys et al.
6,227,679	B1		5/2001	Zhang et al.
6,281,632	B1		8/2001	Stam et al.
6,340,868	B1		1/2002	Lys et al.
6,346,777	B1		2/2002	Kim
6,379,022	B1		4/2002	Amerson et al.
6,385,352	B1		5/2002	Roustaei
6,394,614	B1		5/2002	Chang
6,406,172	B1		6/2002	Harbers et al.
6,483,439	B1		11/2002	Vukosic
6,498,440	B2		12/2002	Stam et al.
6,499,860	B2		12/2002	Begemann
6,528,954	B1		3/2003	Lys et al.
6,587,573	B1		7/2003	Stam et al.
6,601,982	B1		8/2003	Begemann et al.
6,676,282	B2		1/2004	Begemann et al.
6,820,998	B2		11/2004	Chen
6,861,809	B2		3/2005	Stam
7,524,097	B2		4/2009	Turnbull et al.
8,045,760	B2		10/2011	Stam et al.
8,115,394	B2		2/2012	Kobayashi
8,665,079	B2		3/2014	Pawlicki et al.
9,398,270	B2		7/2016	Liken et al.
2001/0014019	A1		8/2001	Begemann
2002/0022774	A1		2/2002	Kamieli
2002/0022927	A1		2/2002	Lemelson et al.
2002/0039238	A1		4/2002	Chang
2002/0046100	A1		4/2002	Kinjo
2002/0047628	A1		4/2002	Morgan et al.
2002/0047646	A1		4/2002	Lys et al.
2002/0057340	A1		5/2002	Fernandez et al.
2002/0130326	A1		9/2002	Tamura et al.
2004/0052076	A1		3/2004	Mueller
2004/0061605	A1		4/2004	Howard
2004/0105264	A1		6/2004	Spero
2004/0138726	A1		7/2004	Savage et al.
2004/0230358	A1		11/2004	Stam et al.
2006/0222213	A1		10/2006	Kiyohara et al.
2008/0136356	A1		6/2008	Zampini et al.
2009/0315485	A1		12/2009	Verfuerth et al.
2010/0052550	A1		3/2010	Kobayashi
2010/0286896	A1	*	11/2010	Yamada G01C 21/30 701/117
2010/0302779	A1		12/2010	Chemel
2011/0211110	A1		9/2011	Doublet
2012/0001547	A1	*	1/2012	Nishitani H05B 45/52 315/82
2012/0001566	A1		1/2012	Josefowicz
2012/0050074	A1	*	3/2012	Bechtel G06K 9/00798 340/988
2012/0091897	A1		4/2012	O et al.
2012/0262575	A1		10/2012	Champagne
2012/0283908	A1		11/2012	Schofield et al.
2012/0287493	A1		11/2012	Kuhlman et al.
2013/0258688	A1		10/2013	Kalapodas

* cited by examiner

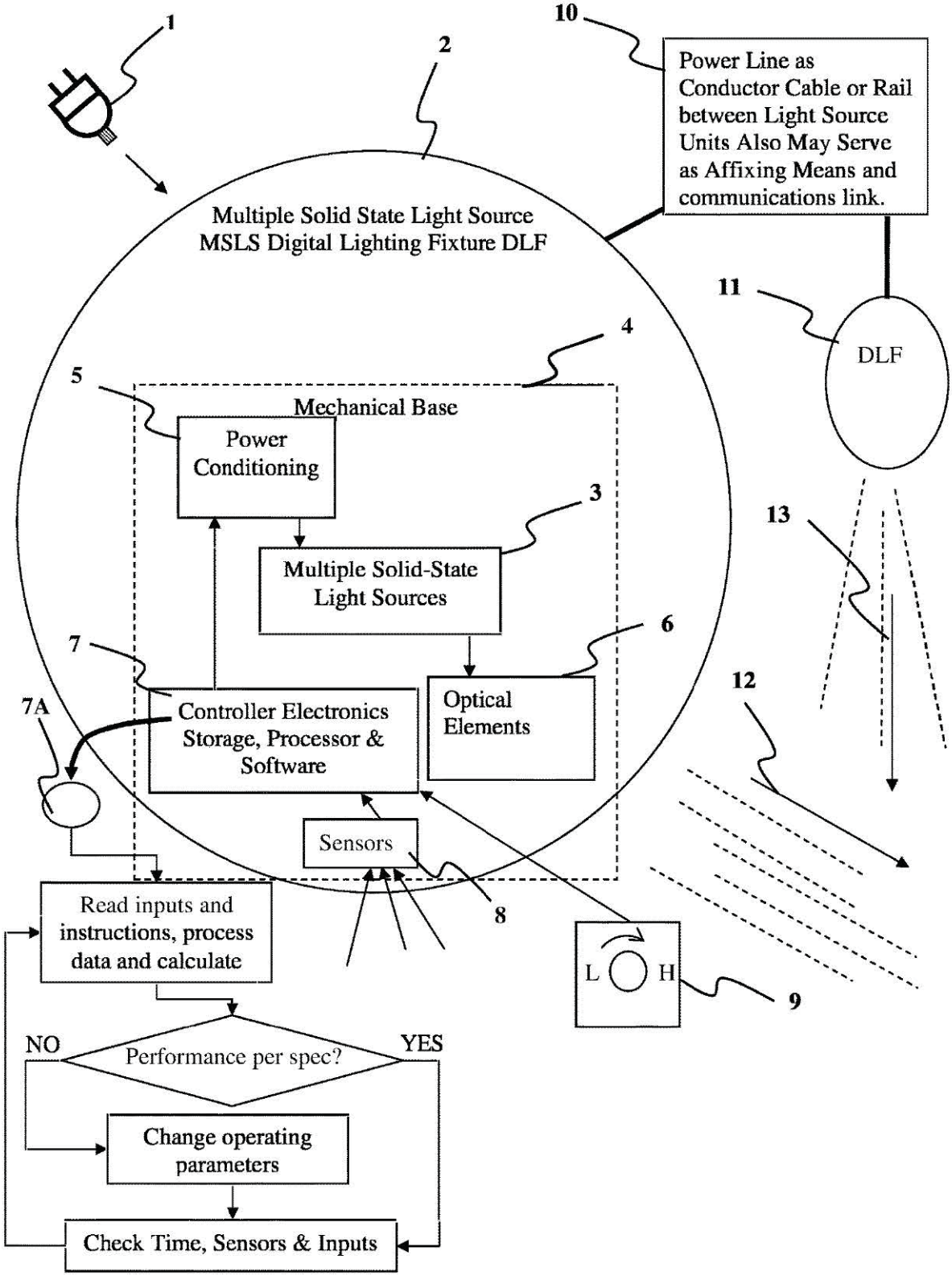

1
2
10
Power Line as Conductor Cable or Rail between Light Source Units Also May Serve as Affixing Means and communications link.
Multiple Solid State Light Source
MSLS Digital Lighting Fixture DLF
11
DLF
4
5
Mechanical Base
Power Conditioning
3
Multiple Solid-State Light Sources
6
7
7A
Controller Electronics Storage, Processor & Software
Optical Elements
13
12
Sensors
8
Read inputs and instructions, process data and calculate
L
H
9
NO
Performance per spec?
YES
Change operating parameters
Check Time, Sensors & Inputs

FIG. 1

PRIOR ART

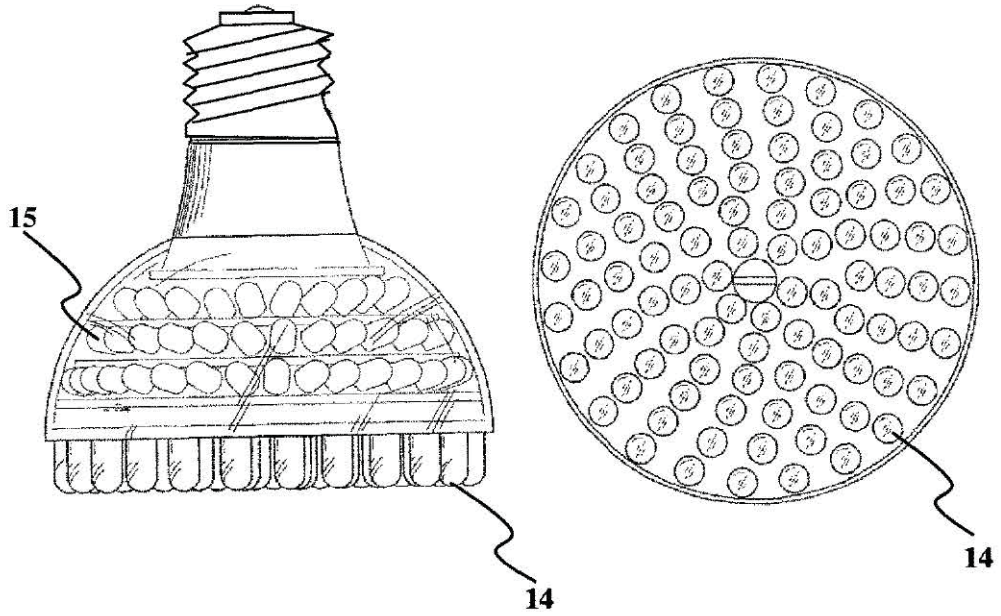


FIG. 2A

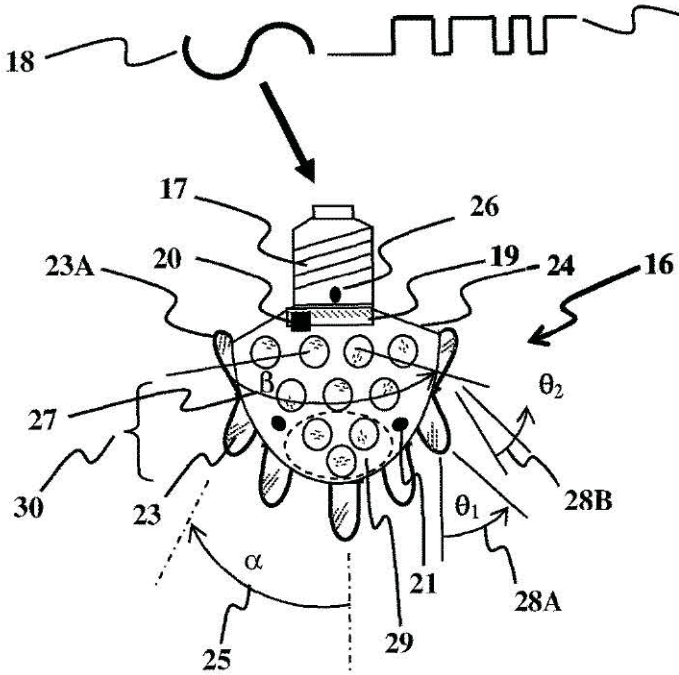


FIG. 2B

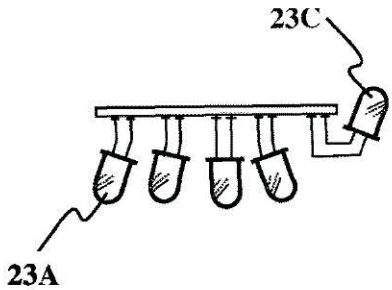


FIG. 2C

PRIOR ART

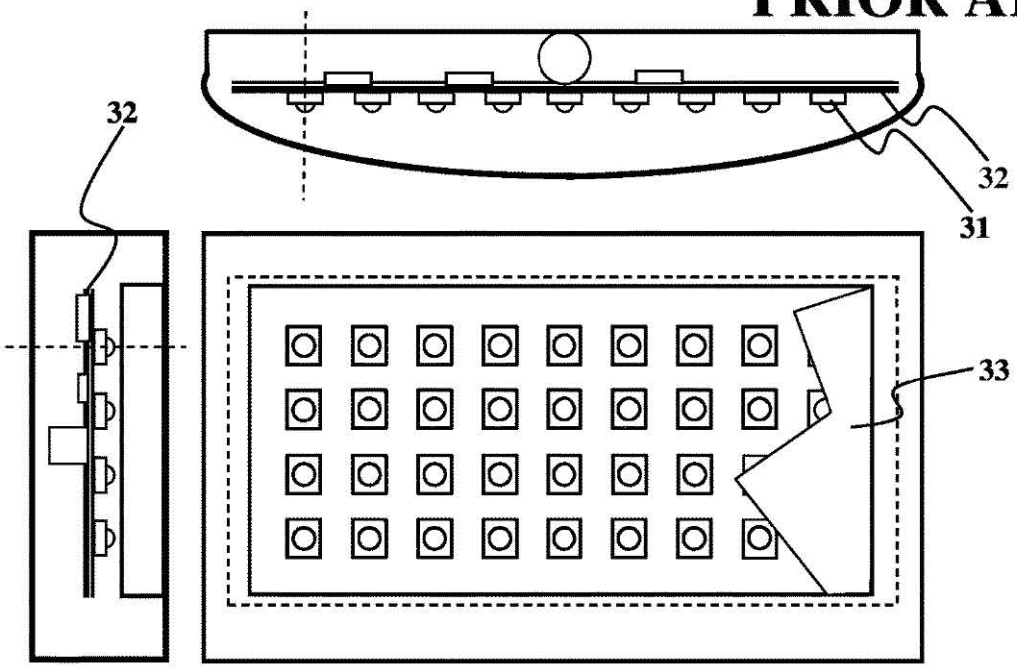


FIG. 3A

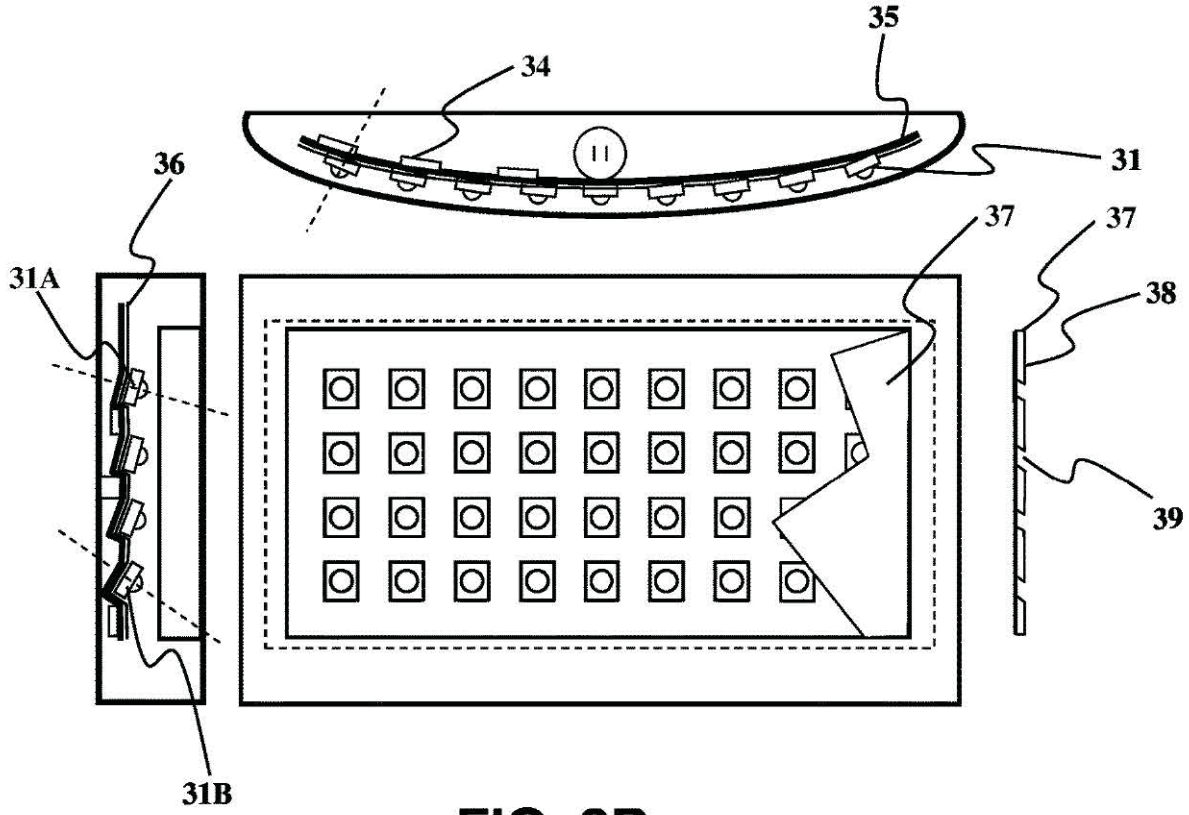


FIG. 3B

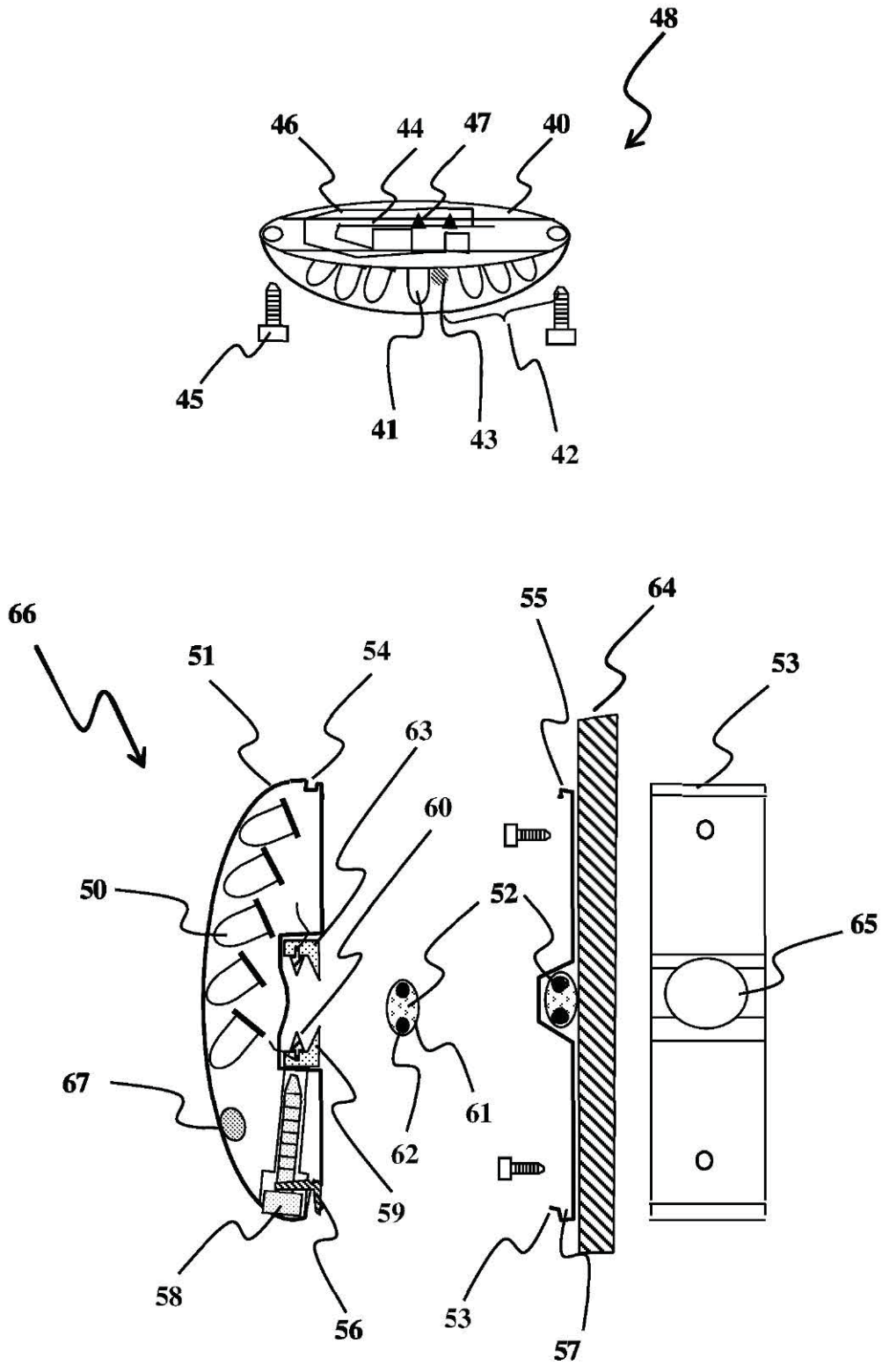

48
46
44
47
40
45
41
43
42
66
51
54
63
60
50
52
55
64
53
65
67
61
62
59
58
56
53
57

FIG. 4

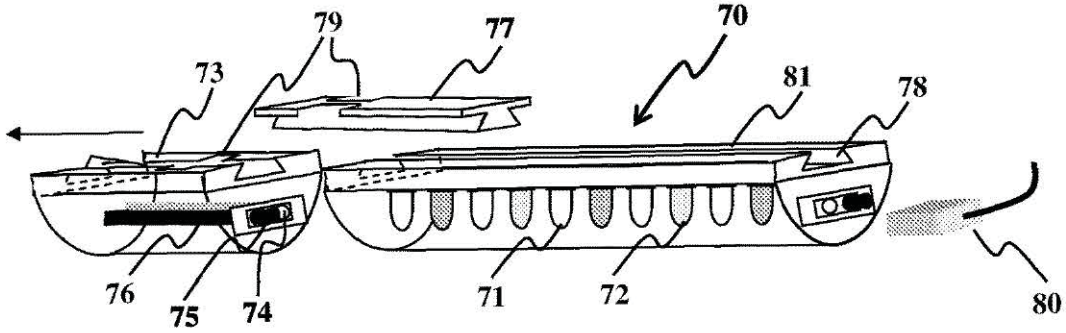

79
77
70
73
81
78
76
75
74
71
72
80

FIG. 5

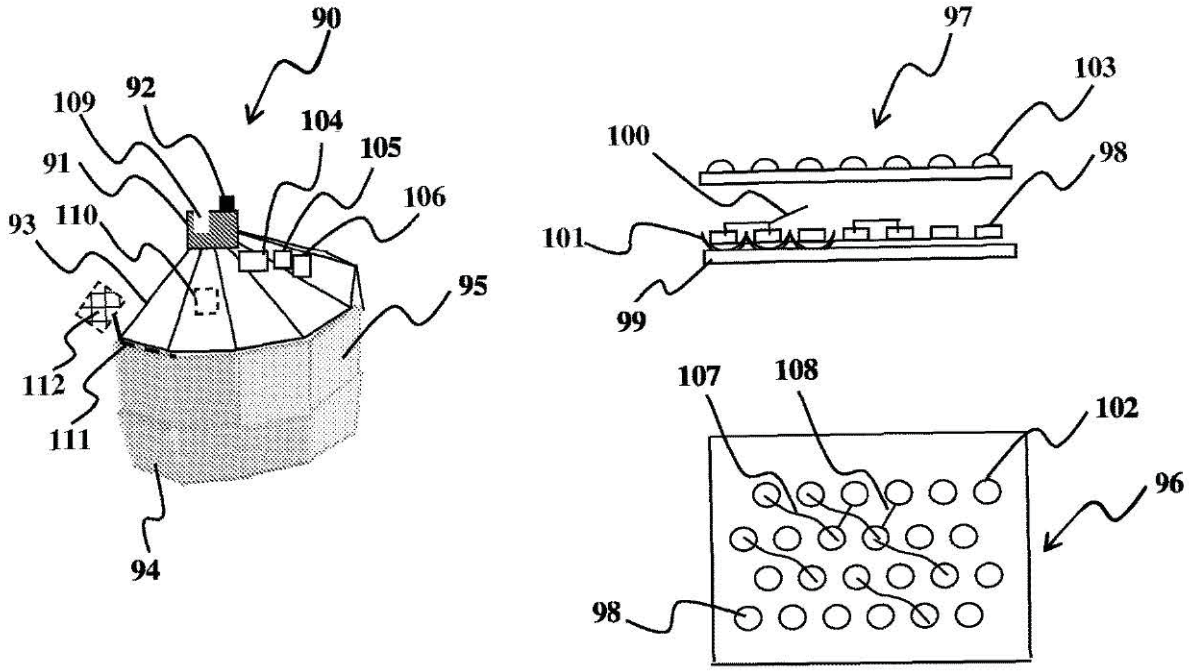

90
109
92
104
105
91
106
93
110
95
112
111
94
97
103
100
98
101
99
107
108
102
96
98

FIG. 6

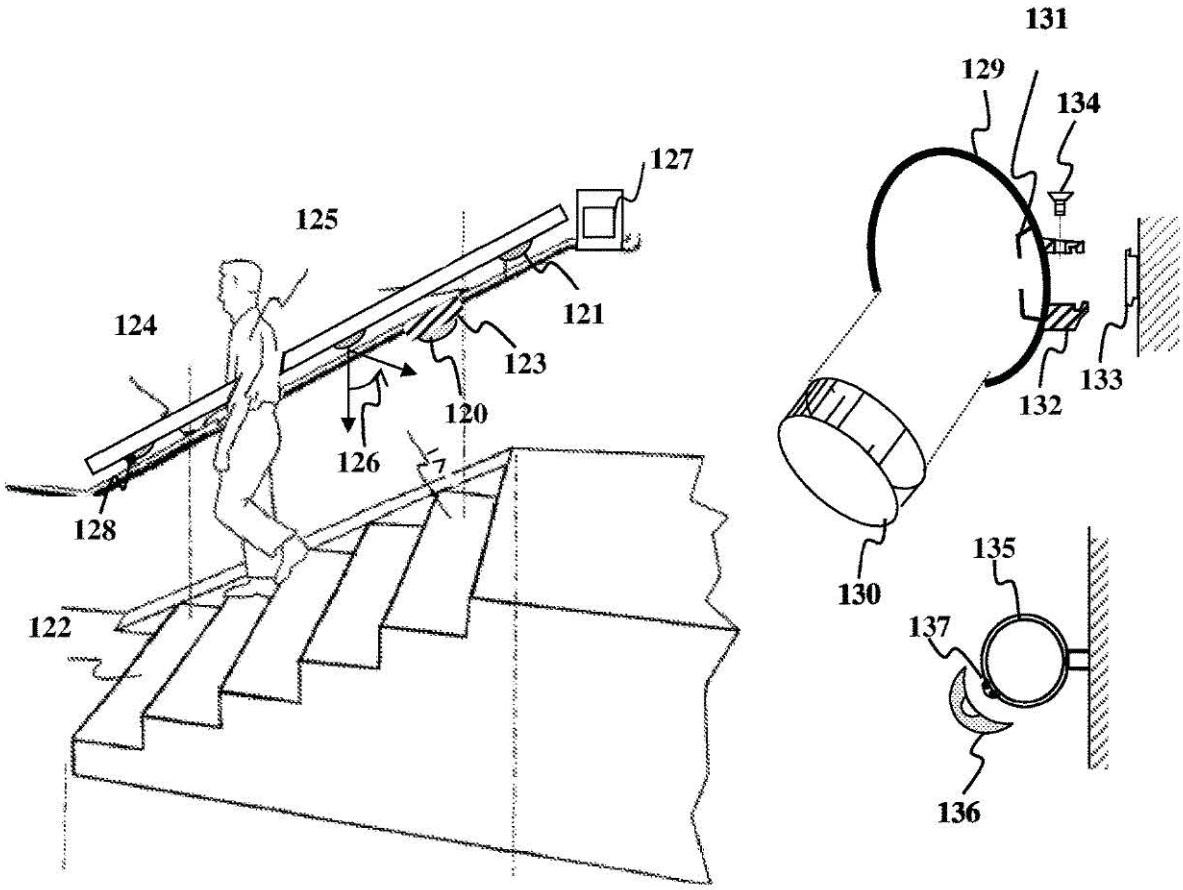

131
129
134
127
125
124
121
123
120
126
133
132
128
130
135
137
122
136

FIG. 7

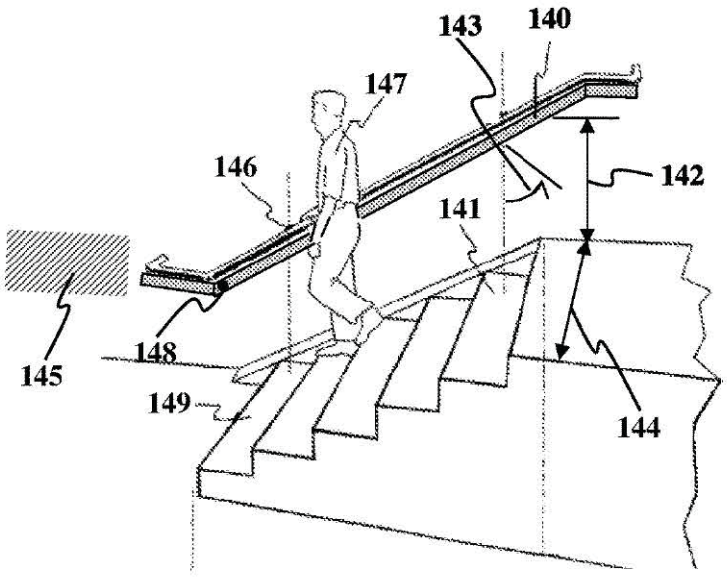

143
140
147
146
142
141
145
148
149
144

FIG. 8

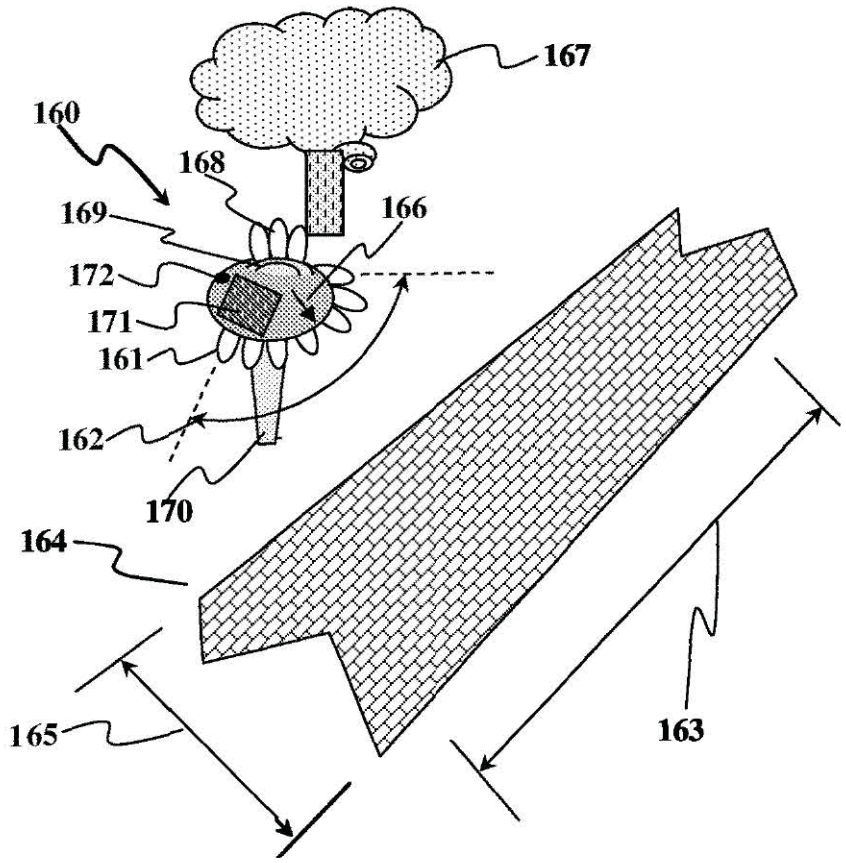

167
160
168
169
166
172
171
161
162
170
164
165
163

FIG. 9

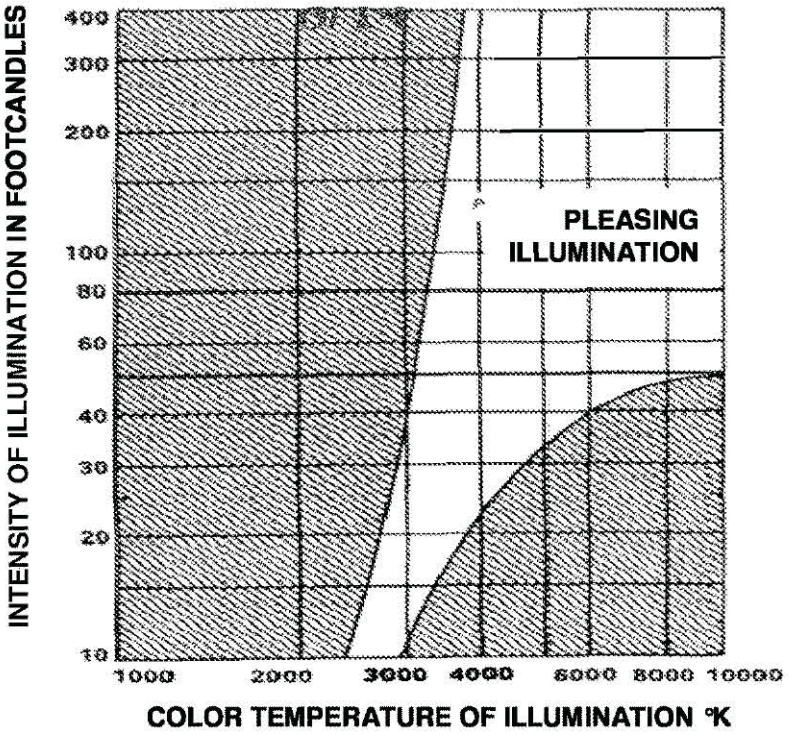

INTENSITY OF ILLUMINATION IN FOOTCANDLES
400
300
200
100
80
60
40
30
20
10
PLEASING
ILLUMINATION
1000
2000
3000
4000
6000
8000
10000
COLOR TEMPERATURE OF ILLUMINATION °K

FIG. 10

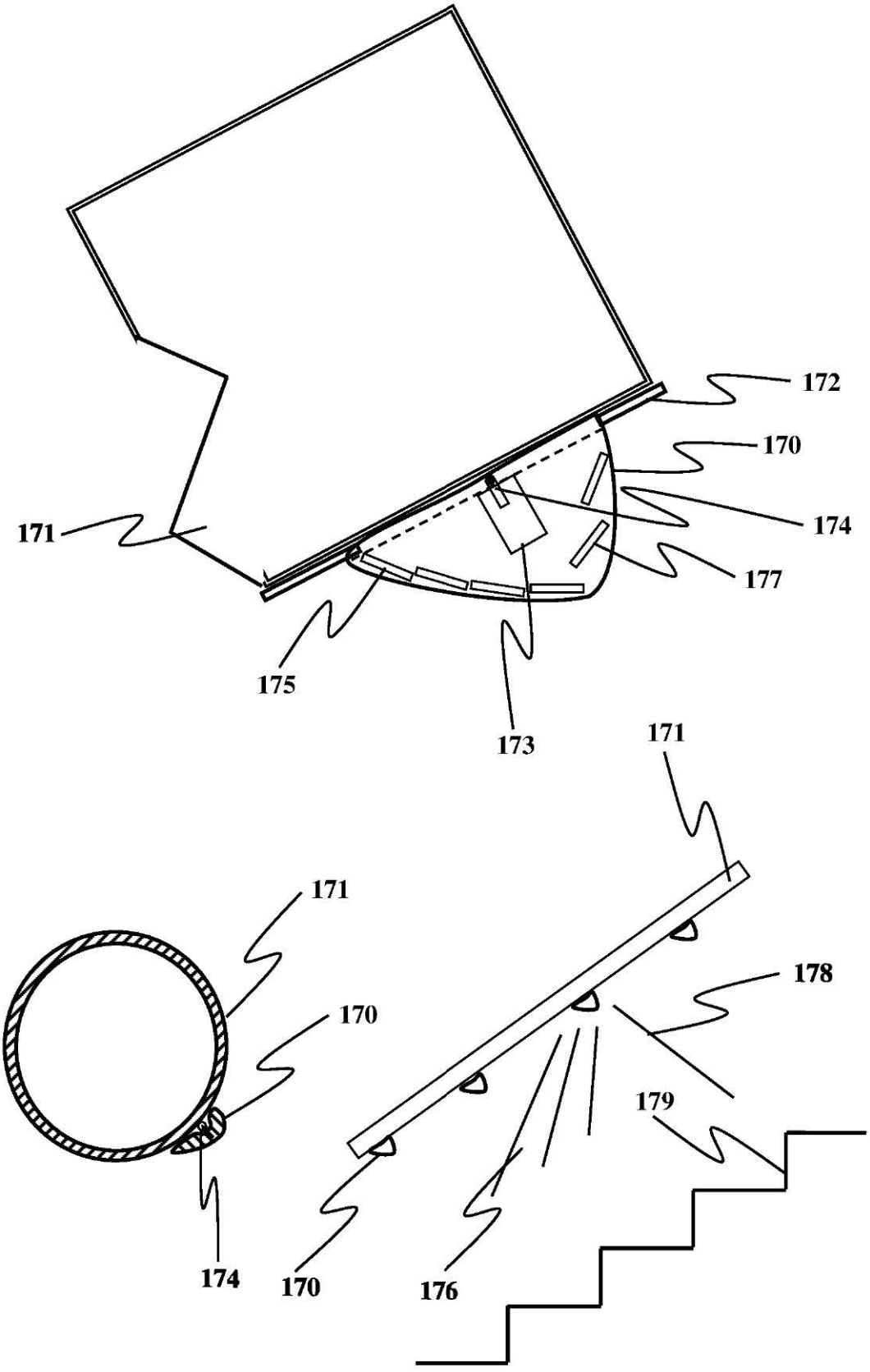


FIG. 11

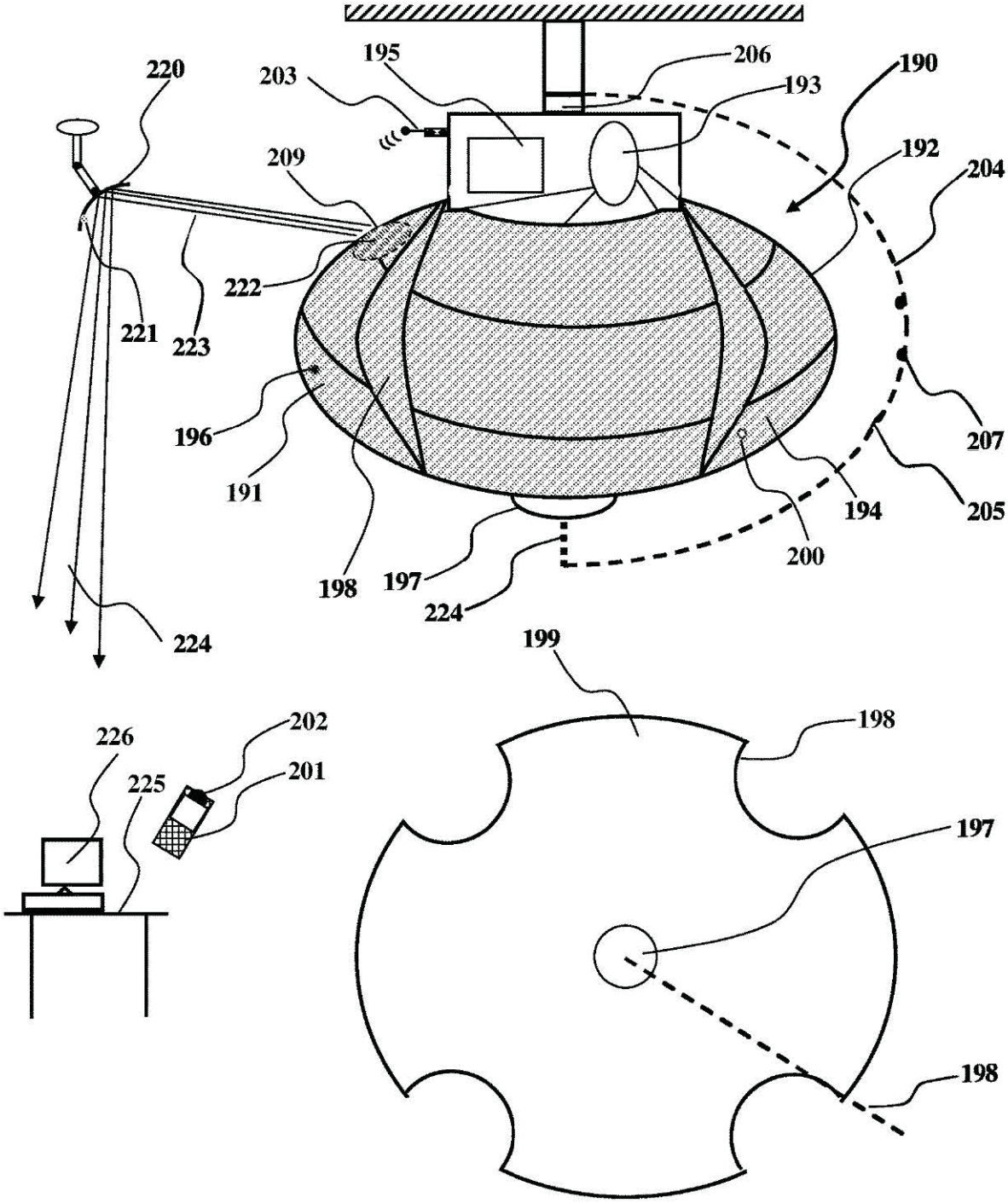

220
203
195
206
190
193
209
192
204
222
221
223
196
191
207
205
194
200
198
197
224
199
226
202
201
225
198
197
198

FIG. 12

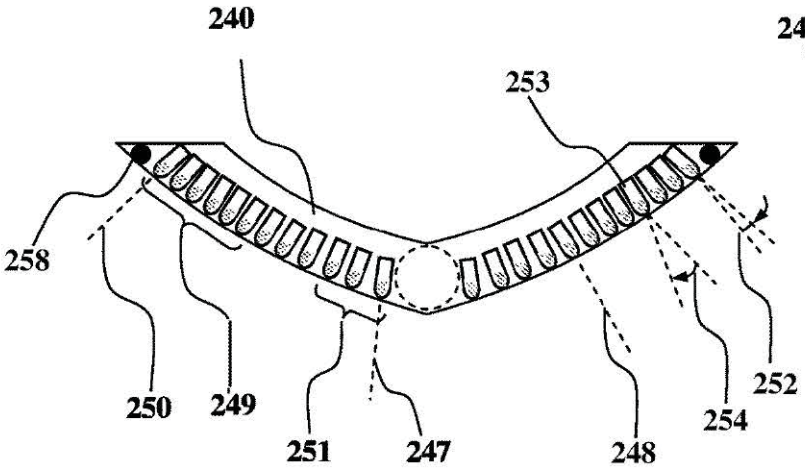


FIG. 13A

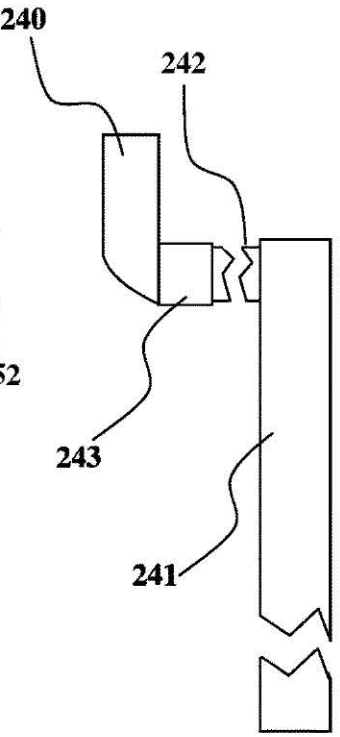


FIG. 13B

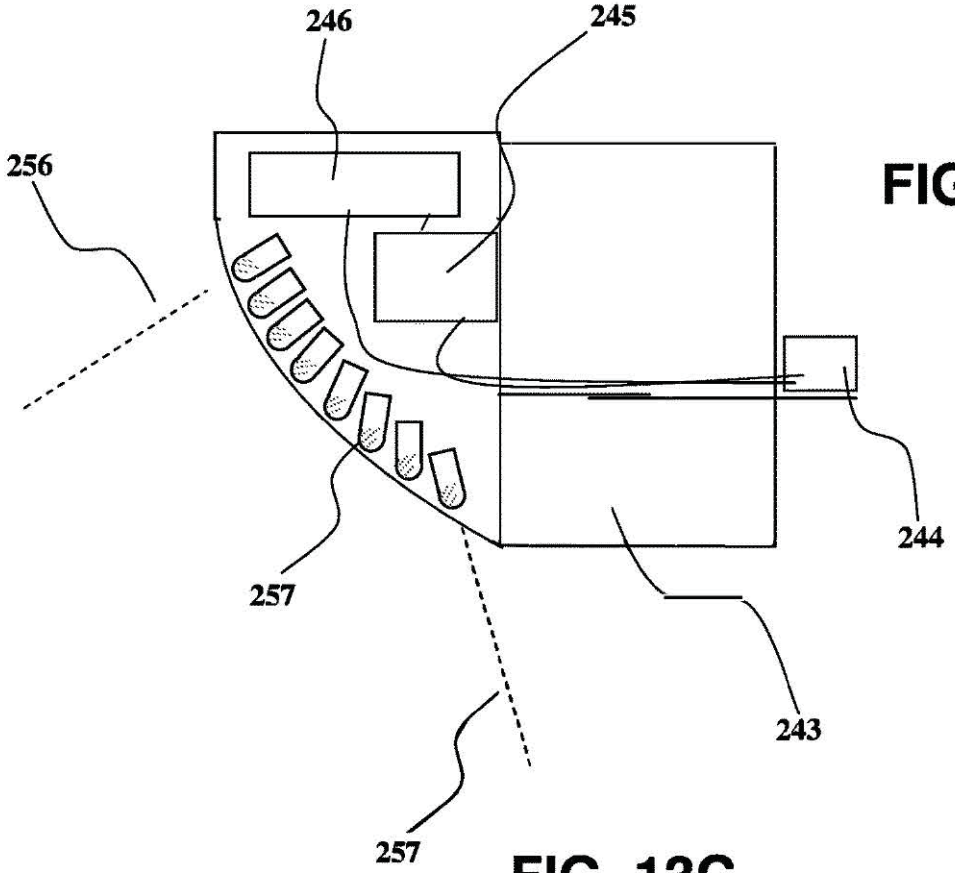


FIG. 13C

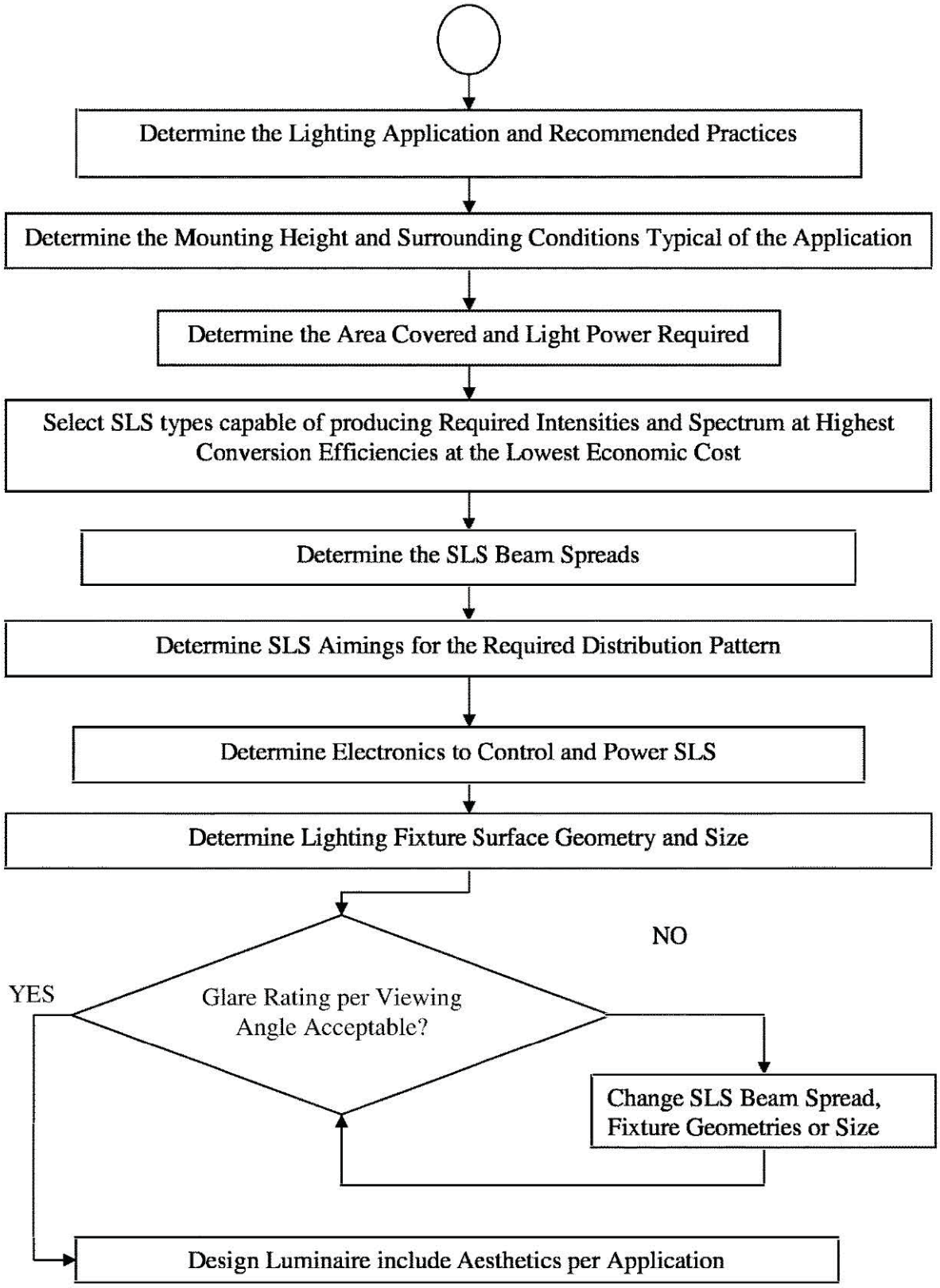

Determine the Lighting Application and Recommended Practices
Determine the Mounting Height and Surrounding Conditions Typical of the Application
Determine the Area Covered and Light Power Required
Select SLS types capable of producing Required Intensities and Spectrum at Highest Conversion Efficiencies at the Lowest Economic Cost
Determine the SLS Beam Spreads
Determine SLS Aimings for the Required Distribution Pattern
Determine Electronics to Control and Power SLS
Determine Lighting Fixture Surface Geometry and Size
Glare Rating per Viewing Angle Acceptable?
NO
YES
Change SLS Beam Spread, Fixture Geometries or Size
Design Luminaire include Aesthetics per Application

FIG. 14

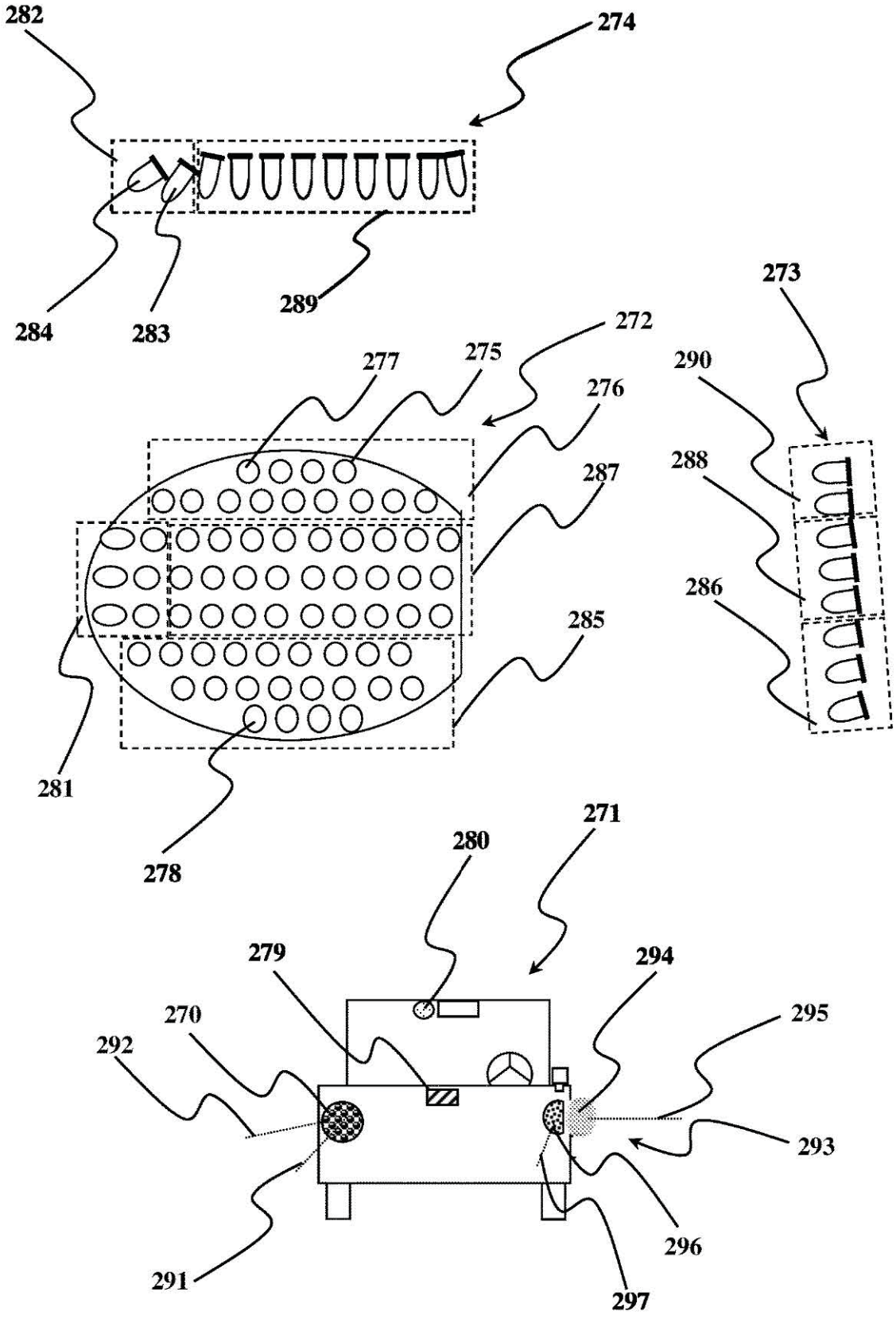

282
274
284
283
289
273
272
277
275
276
290
288
287
286
285
281
278
271
280
279
294
270
295
292
293
296
291
297

FIG. 15

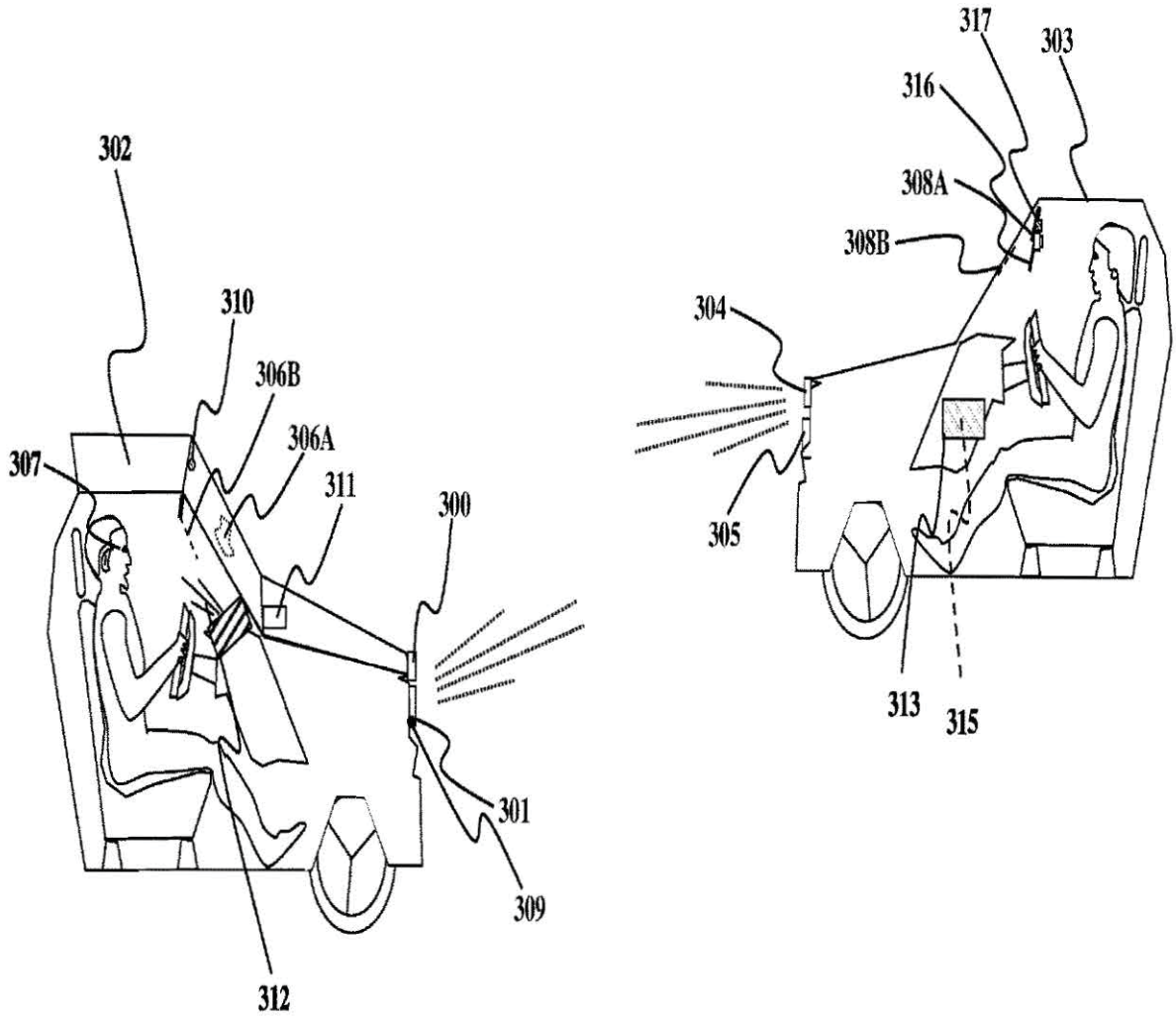

317
303
316
308A
308B
304
305
313
315
302
310
306B
306A
307
311
300
301
309
312

FIG. 16

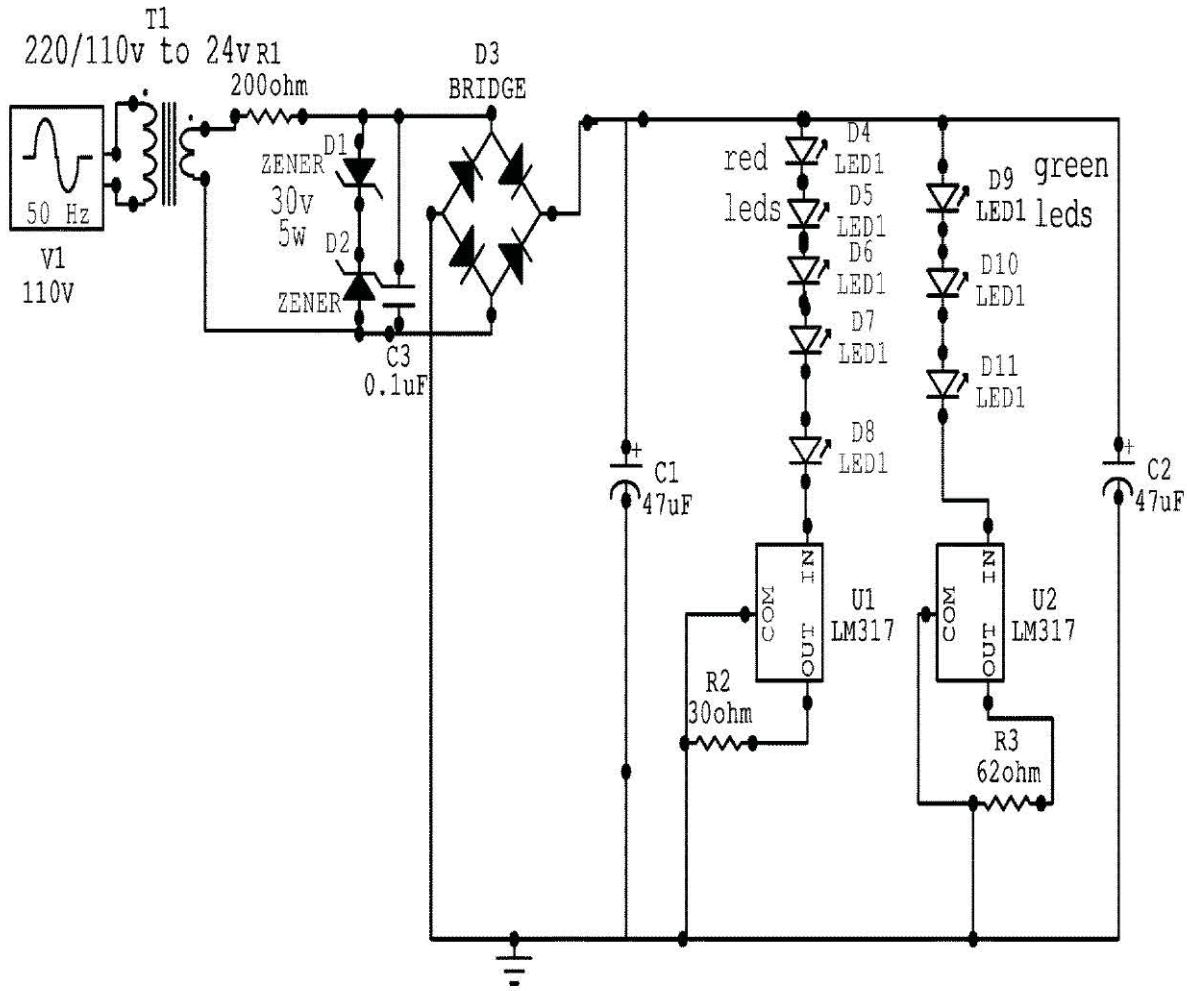

T1
220/110v to 24v
R1
200ohm
D3
BRIDGE
50 Hz
V1
110V
ZENER
D1
30v
5W
D2
ZENER
C3
0.1uF
red
leds
D4
LED1
D5
LED1
D6
LED1
D7
LED1
D8
LED1
D9
LED1
green
leds
D10
LED1
D11
LED1
C1
47uF
C2
47uF
COM
IN
OUT
U1
LM317
U2
LM317
R2
30ohm
R3
62ohm

FIG. 17

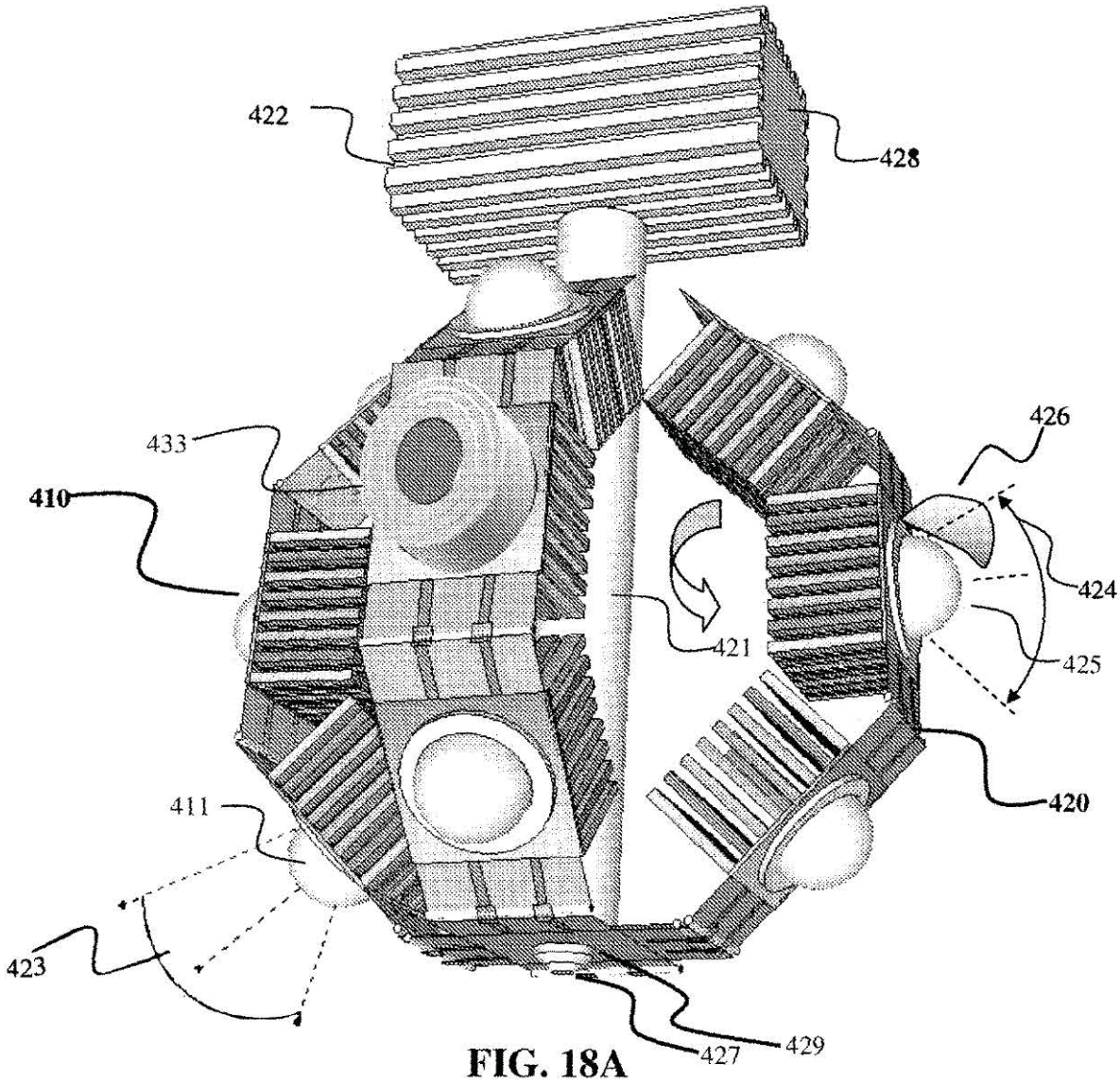


FIG. 18A

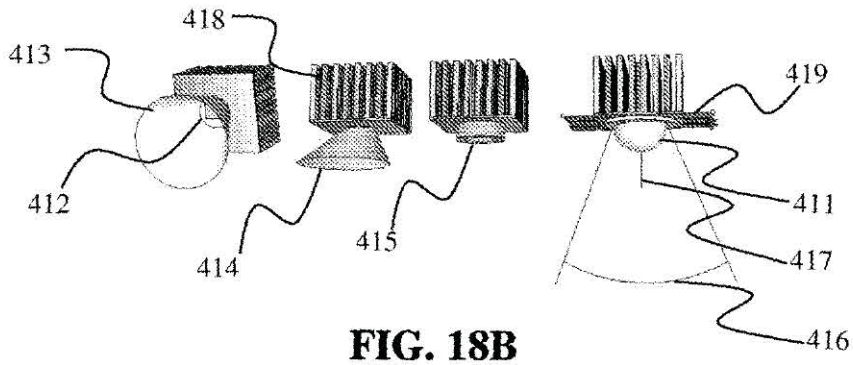


FIG. 18B

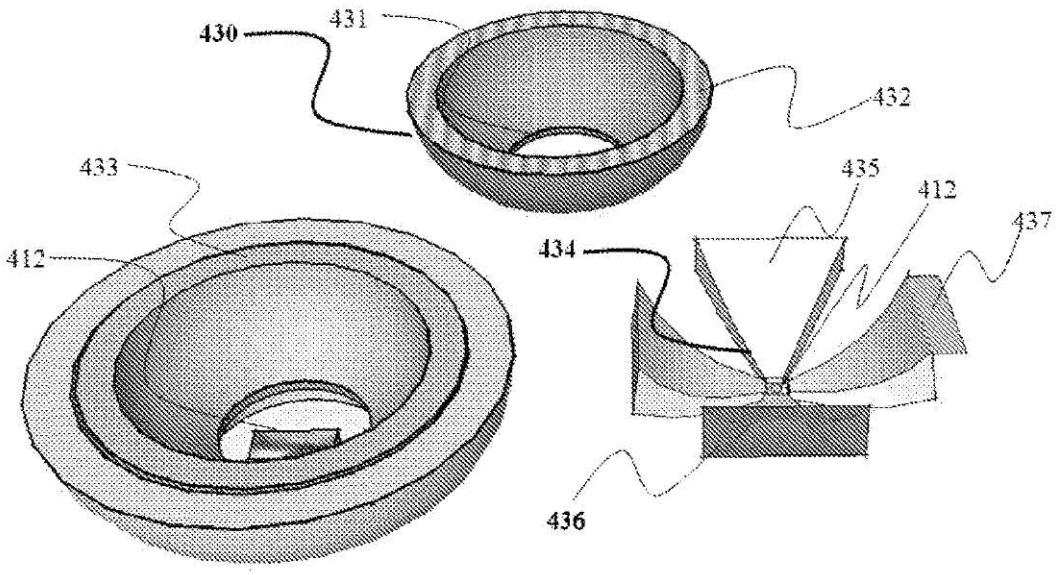


FIG. 19

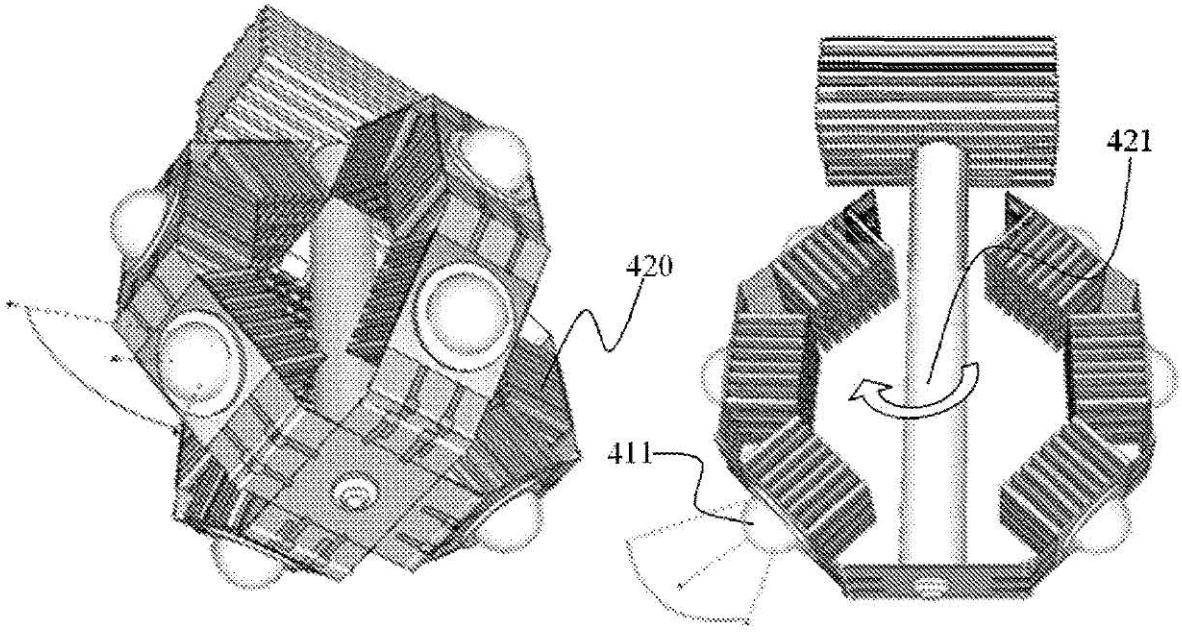


FIG. 20A

FIG. 20B

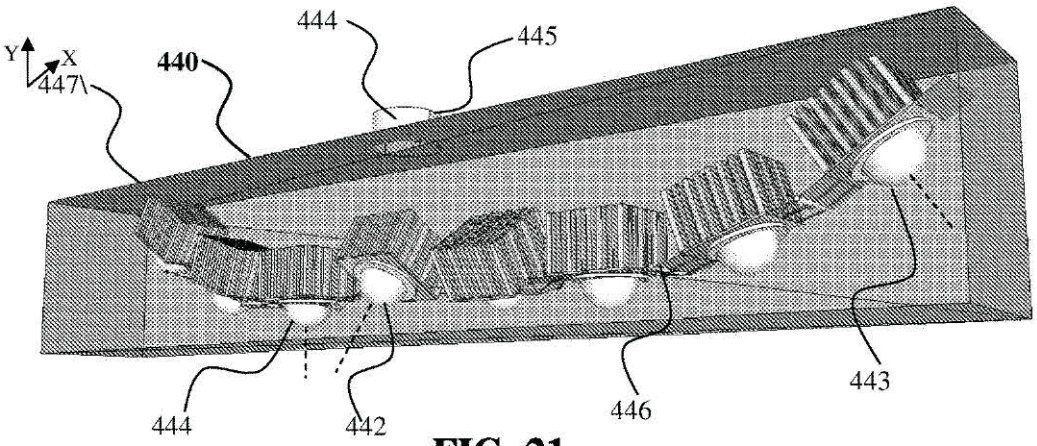

Y
X
447
440
444
445
444
442
446
443

FIG. 21

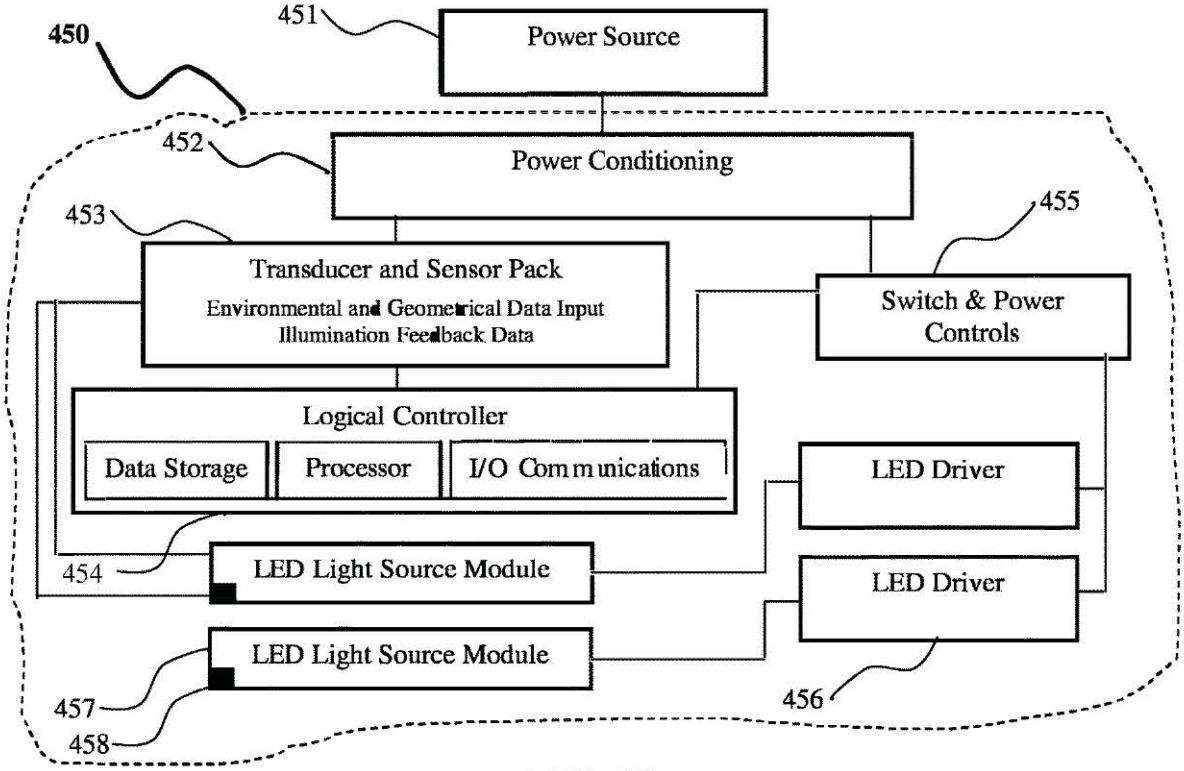

450
451
Power Source
452
Power Conditioning
453
Transducer and Sensor Pack
Environmental and Geometrical Data Input
Illumination Feedback Data
455
Switch & Power Controls
Logical Controller
Data Storage
Processor
I/O Communications
LED Driver
454
LED Light Source Module
LED Driver
LED Light Source Module
457
458
456

FIG. 22

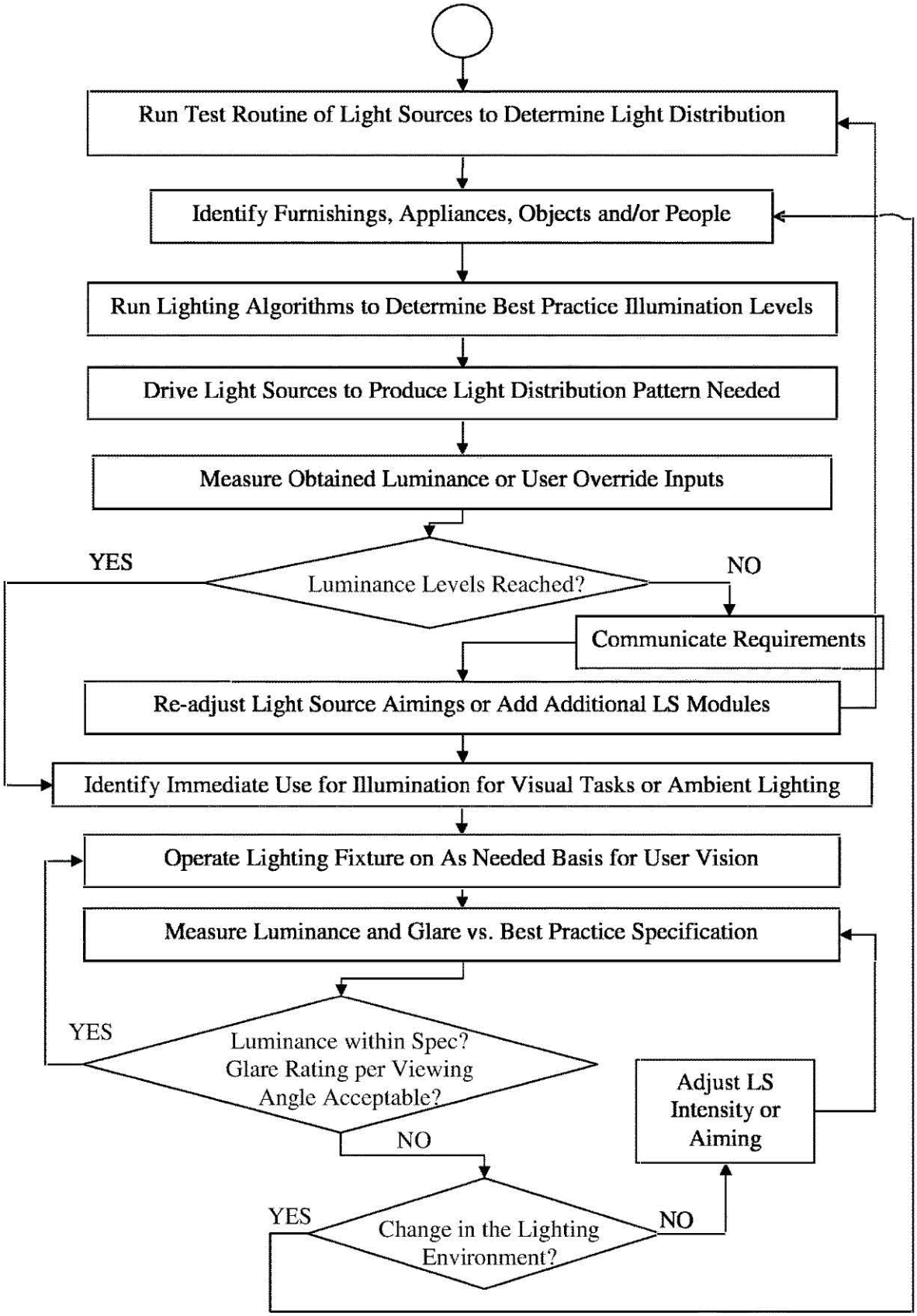

Run Test Routine of Light Sources to Determine Light Distribution
Identify Furnishings, Appliances, Objects and/or People
Run Lighting Algorithms to Determine Best Practice Illumination Levels
Drive Light Sources to Produce Light Distribution Pattern Needed
Measure Obtained Luminance or User Override Inputs
YES
Luminance Levels Reached?
NO
Communicate Requirements
Re-adjust Light Source Aimings or Add Additional LS Modules
Identify Immediate Use for Illumination for Visual Tasks or Ambient Lighting
Operate Lighting Fixture on As Needed Basis for User Vision
Measure Luminance and Glare vs. Best Practice Specification
YES
Luminance within Spec? Glare Rating per Viewing Angle Acceptable?
Adjust LS Intensity or Aiming
NO
YES
Change in the Lighting Environment?
NO

Fig. 23

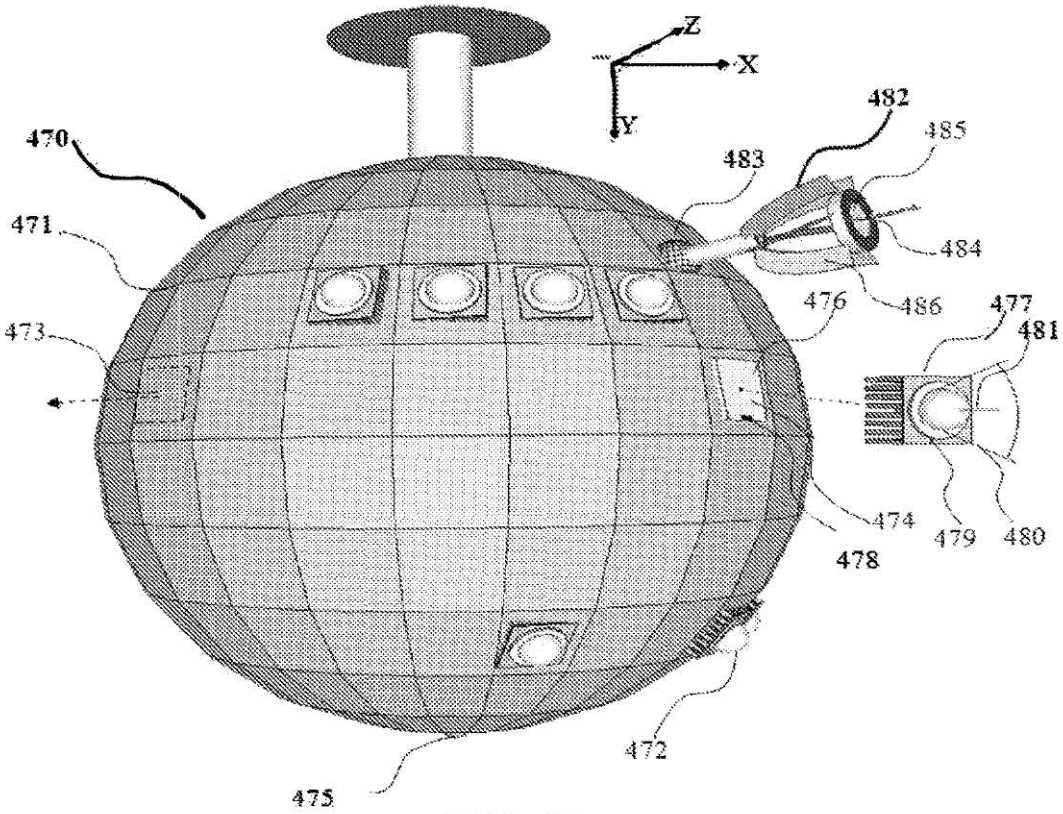


FIG. 24

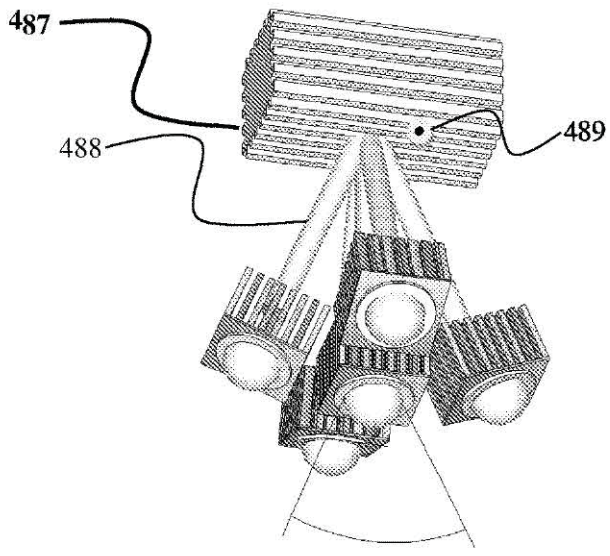


FIG. 25A

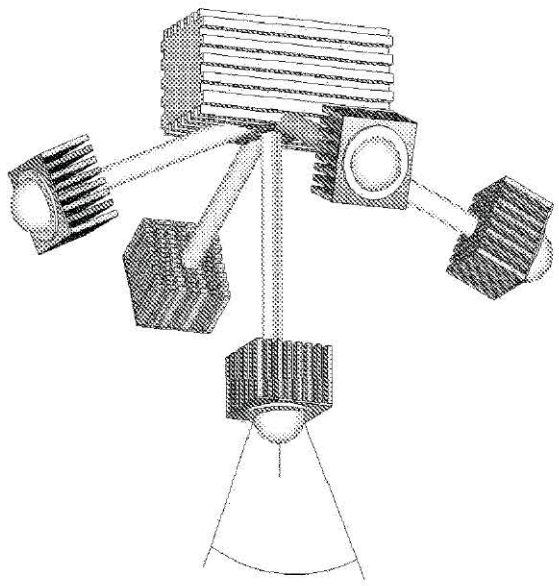


FIG. 25B

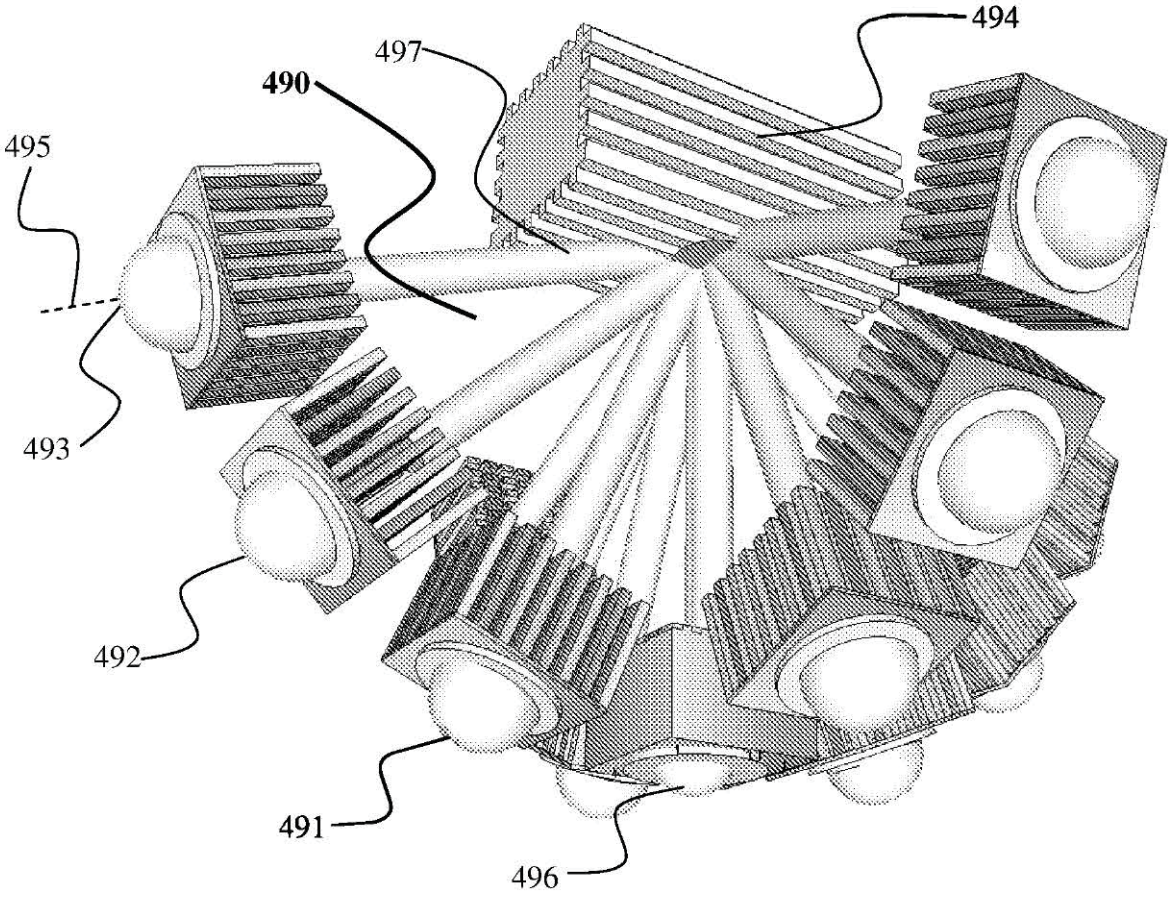


FIG. 26

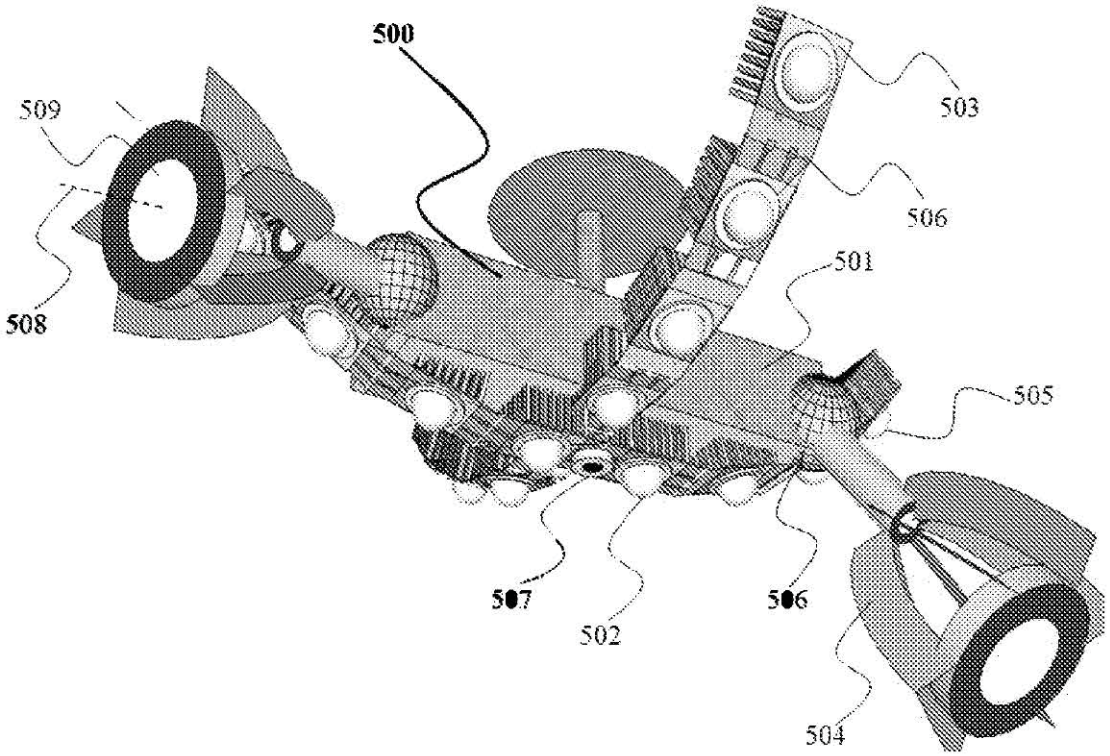


FIG. 27

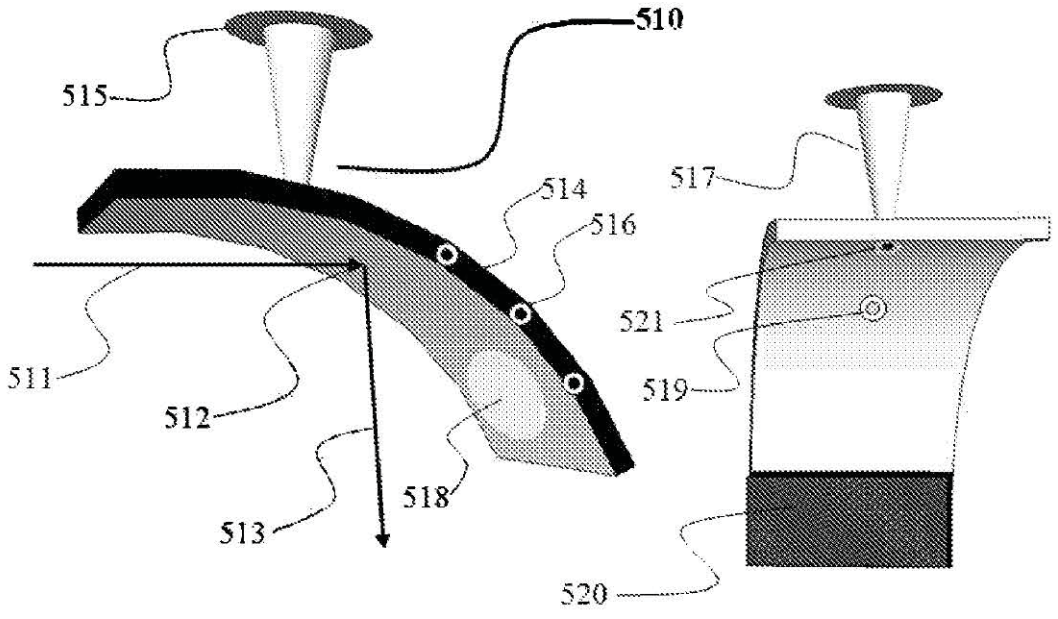


FIG. 28A

FIG. 28B

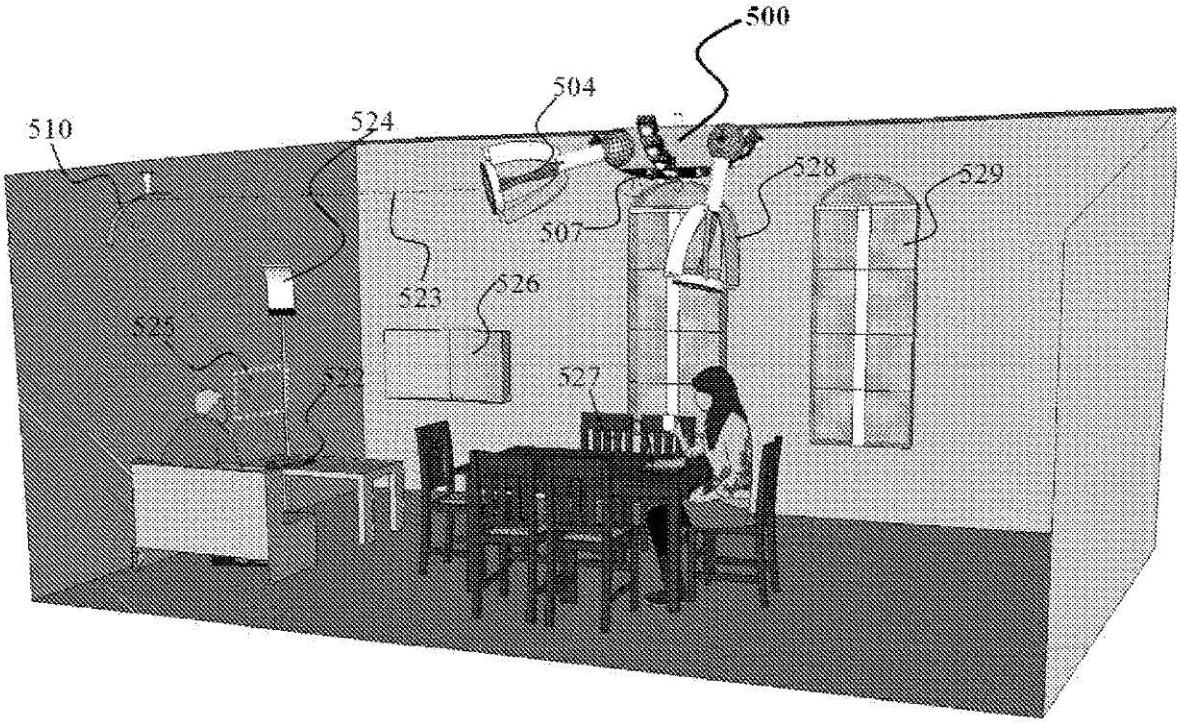

500
504
510
524
528
529
507
523
526
525
527

FIG. 29

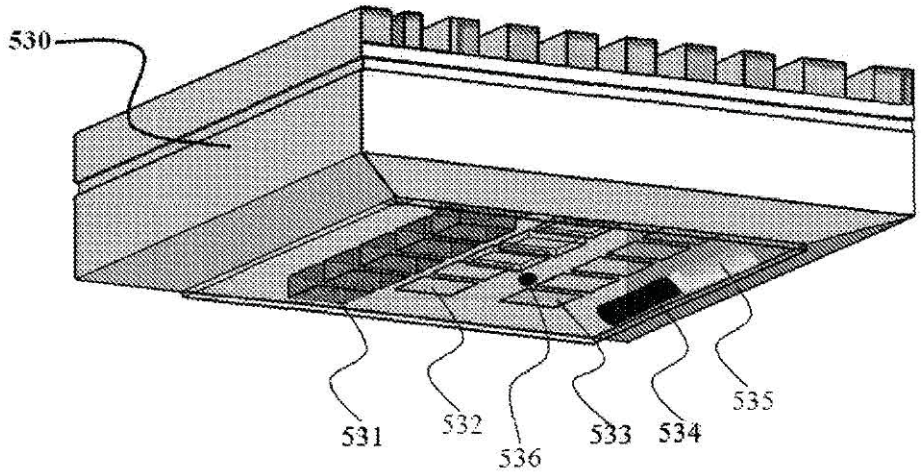

530
531
532
536
533
534
535

FIG. 30

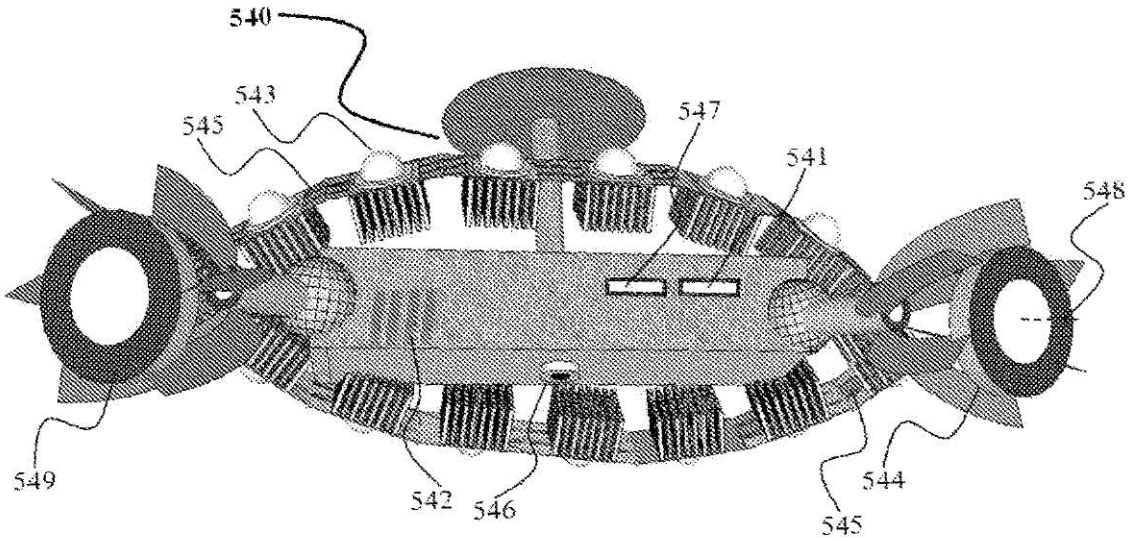

540
543
545
547
541
548
549
542
546
544
545

FIG. 31

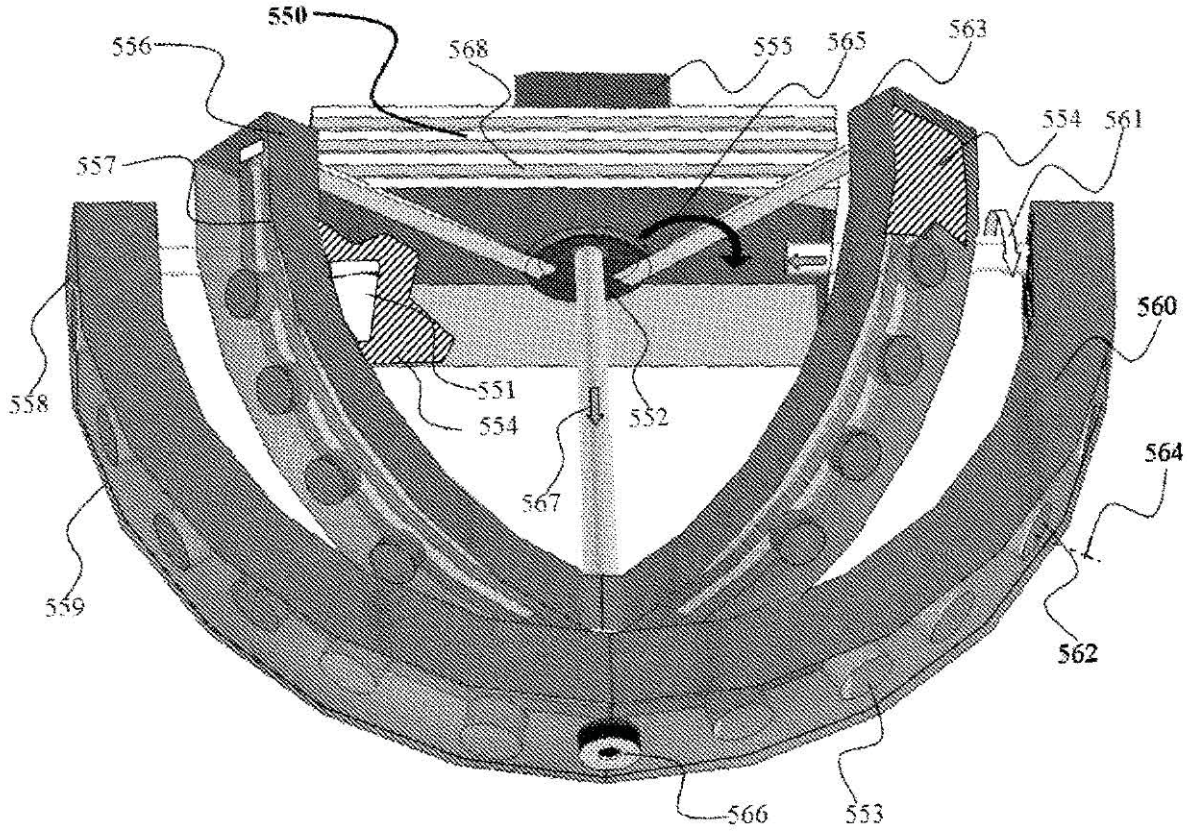

550
556
568
555
565
563
554
561
557
560
558
551
554
552
564
567
559
562
566
553

FIG. 32

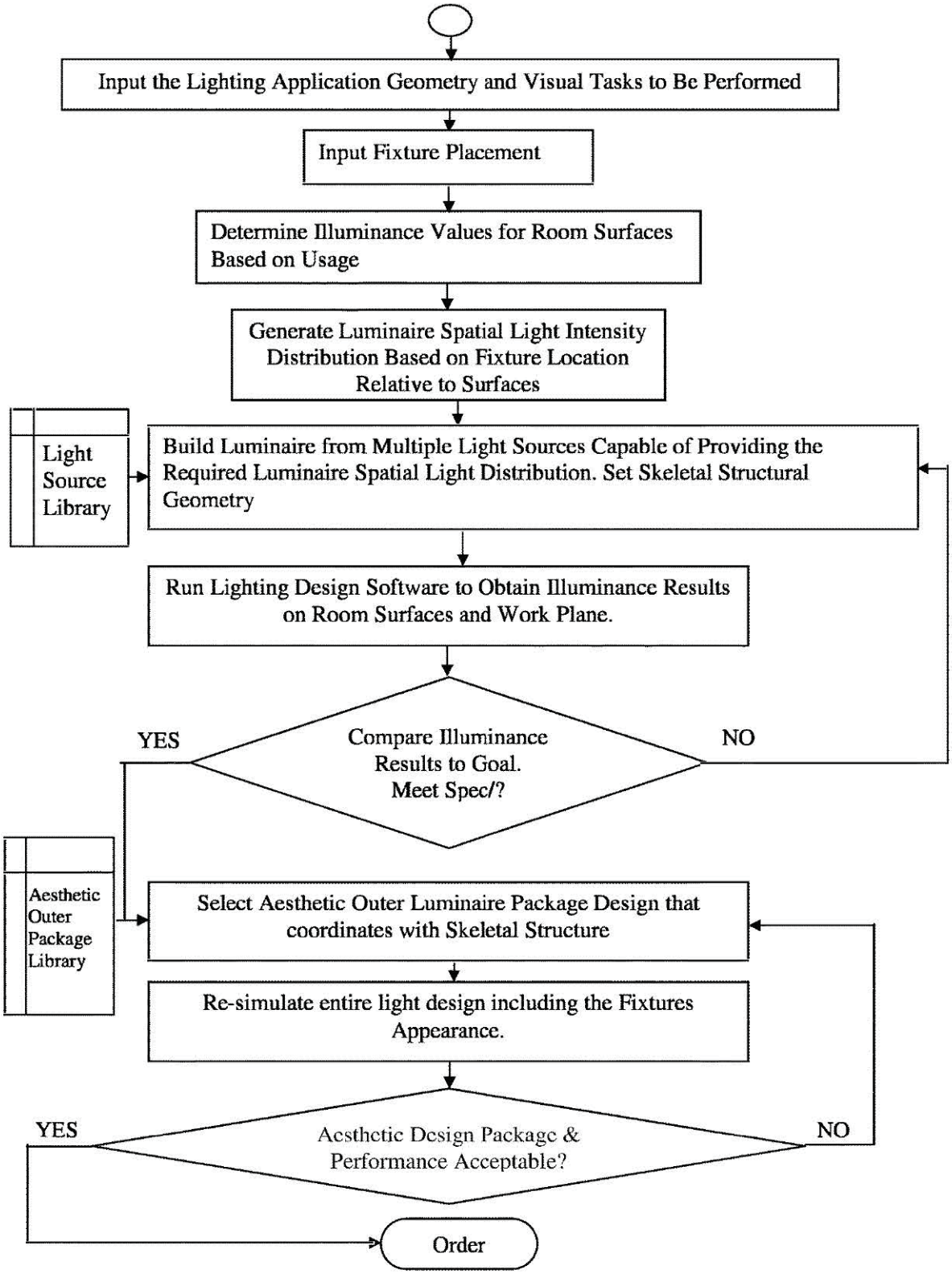

Input the Lighting Application Geometry and Visual Tasks to Be Performed
Input Fixture Placement
Determine Illuminance Values for Room Surfaces Based on Usage
Generate Luminaire Spatial Light Intensity Distribution Based on Fixture Location Relative to Surfaces
Light Source Library
Build Luminaire from Multiple Light Sources Capable of Providing the Required Luminaire Spatial Light Distribution. Set Skeletal Structural Geometry
Run Lighting Design Software to Obtain Illuminance Results on Room Surfaces and Work Plane.
Compare Illuminance Results to Goal. Meet Spec/?
YES
NO
Aesthetic Outer Package Library
Select Aesthetic Outer Luminaire Package Design that coordinates with Skeletal Structure
Re-simulate entire light design including the Fixtures Appearance.
Aesthetic Design Package & Performance Acceptable?
YES
NO
Order

FIG. 33

ADAPTIVE HEADLIGHT SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of U.S. patent application Ser. No. 15/961,861 filed Apr. 24, 2018, now U.S. Pat. No. 10,894,503 which issued Jan. 19, 2021 which is a Continuation of U.S. patent application Ser. No. 13/357,549 filed Jan. 24, 2012, now U.S. Pat. No. 9,955,551 which issued Apr. 24, 2018, which is a Continuation-in-Part of U.S. patent application Ser. No. 10/604,360, entitled "Multiple Light-Source Illuminating System" filed on Jul. 14, 2003, now U.S. Pat. No. 8,100,552 which issued on Jan. 24, 2012, which claims benefit under 35 U.S.C., § 119(e) of U.S. Provisional Application No. 60/395,308 filed Jul. 12, 2002, entitled "Multiple Light Source Illumination System". U.S. patent application Ser. No. 13/357,549 filed Jan. 24, 2012, also claims benefit of U.S. Provisional Application No. 61/535,981 filed Sep. 17, 2011 entitled "Adjustable Light Fixture" The entire content of the disclosures are all expressly incorporated herein by reference.

TECHNICAL FIELD

The present invention is in the field of radiation producing devices. More particularly, the present invention is in the technical field of lighting fixtures. However, radiation used for headlamps, heating, night vision, UV or visible light curing, medical X-rays and other radiation uses are covered as well. General lighting fixtures otherwise known as luminaires will be used as the primary example while other irradiating devices such as infrared heaters are covered as well. The invention relates to multiple light source illuminating devices intended to replace incandescent, fluorescent and HID luminaries in general and specialty lighting applications.

BACKGROUND

Definitions, Terms, Elements

In order to clarify the intent of the present invention and its dissimilar aspects from prior art, a nomenclature system is established.

Used herein illumination refers to the deliberate application of light to achieve some practical or aesthetic effect. Correct illumination or recommend lighting practice refers to lighting industry standards and recommendations for the illumination of living, recreation, architectural and work areas as described in standards and handbooks published by industry professional organizations such as the Illuminating Engineering Society, the International Association of Lighting Designers, IALD or International Commission on Illumination CIE.

Lamp: A lamp, other than a reflector lamp, is generally a device that generates light radially from the source. Due to the physics involved in the light generation process, it is difficult at the source to gain control of the spatial light propagation. A reflector lamp will partially control the emitted light which hits the reflector but will not control the remaining light emanating from the filament or discharge tube. A lamp other than a solid-state lamp will generally produce light over a wide range of spectrum. The overall color is a function of the physics involved in the generation of the different photon energies. While some lamps spectra are closer to sunlight and have a good color rendering in relation thereto, other lamps such as low-pressure sodium

are highly monochromatic with a yellow-orange appearance. A color temperature in degrees Kelvin based on the color of an incandescent filament is used to describe a lamp. An incandescent lamp color will be termed "warm" at 2000 Kelvin and a Metal Halide "cool" at 4000K. In general, there is no ability to affect the color over the intensity level even where dimming is afforded. A lamp is also intended to be a replaceable element. Lamps are constructed according to universal standards which allow for the substitution of lamps by other manufacturers. Prior-art lamps are thus provided with bulky bases which fit into bulky sockets and do not lend themselves to being permanently wired into printed circuit boards or bonded onto electronic chips.

Luminaire: A Lighting Fixture or luminaire (the terms are used interchangeably) is a device which is constructed around the lamp to provide lighting specific to the application including non-lighting considerations such as aesthetics, safety etc. Some LF designs are primarily based on aesthetics while others are based on tailoring the lumen output such that the lighting fixture output meets the visual task at hand. Between these two extremes there are many possible designs, with maintenance, fixture cost, hazardous and rough service location considerations also playing a role. This is essentially why the industry produces so many different types of luminaires. One type for high industrial building ceilings known as high-bay lighting, another for office lighting and a third for roadway lighting and a fourth for illuminating corridors. Each fixture has its photometric distribution characteristics, that is, how many candela at what angle are exiting from the luminaire. Other luminaire considerations include keeping the lighting from causing discomfort glare or from being a source of veiling reflections. The purely technical goal is to get the required amount of light at the work surfaces where visual tasks are carried out by man, animals, plants and machines. A LF has a longer life than the lamp, and the lamp is meant to be replaceable within the fixture. A luminaire is wired directly to the electrical mains while a lamp due to its need to be replaced has a base which fits into a socket by way of which the lamp receives its power. Prior art solid-state lamp assemblies are considered lamps, as they have no provision for being connected to the mains. A luminaire has apparatus whereby it is attached to the building structure while a lamp is mechanically affixed to the lamp holder or socket. Another aspect of distinction is, that in general, correct lighting practice principles are used to guide in the design of a LF while a lamp is "bare" and is expected to have reflectors, refractors, shades and louvers to prevent glare and redirect its rays to increase light utilization.

Digital: The term digital used herein in refers to the luminaire concept as espoused by teachings of this invention and is loosely defined in parallel to the fine control associated with digital equipment. The multiple light sources of specific characteristics provide quanta of power and spectrum which are smoothly added or detracted to generate a changed lighting effect. The digital aspect arises from the sufficient progression of values, varying by minute degrees to produce a continuum so as be non-discernable or irrelevant to the user. The added controllability is realized by breaking up the light-production, into discrete, specifically aimable, and dimmable elements which can be addressed by control electronics for the purpose of affecting the intensity, spectrum and spatial distribution of spectrum and of intensity of the illumination provided by the luminaire of the present invention.

The overall combination of control capability and discrete light sources yields a digital lighting fixture. The terminol-

ogy "digital" as used herein also refers to the discrete nature of the multiple LED lamps provided in the luminaire, whereby, "digital" control results from the individual control of the discrete, i.e., "digital" lighting elements, the LEDs, in the luminaire.

Correct lighting practice: A bare incandescent lamp illuminating a room is arbitrarily termed poor lighting practice. The bare light bulb hooked up to the electric power via a light switch, causes glare, wastes light, delivering the light to useless areas, has no provision for dimming and is energy inefficient. The Illuminating Engineering Society of North America (IESNA) as well as other professional groups such as the International Association of Lighting Designers (IALD) have developed recommended lighting practices for specific applications in indoor and outdoor lighting. These recommendations and equations for implementing the recommendations can be found in the IESNA Lighting Handbook, 8th and/or 9th Editions (available from the Illuminating Engineering Society of North America 120 Wall St. Floor 17 New York, N.Y. 10005 included herein by reference. Factors in good lighting include lighting intensity levels which may be based on the age of the users of the light, the color rendering capacity of the light source, its color temperature, the non-production of glare, veiling reflections and energy efficiency amongst others. Recommendations for all aspects of lighting in terms of intensity, distribution, color temperature, color temperature as a function of light intensity and correct color rendering exist in the literature in terms of lighting applications that is the environment to be illuminated, in parameters such as lux for intensity, CRI for color rendering index and Visual Comfort Parameter (VCP) for glare. In recent years, the Unified Glare Rating (UGR) as recommended by the CIE has become widely accepted as a general formula for assessing glare. While the US may still use VCP ratings, all the lighting-practice engineering organizations worldwide have standards and recommended ratings for different activities. For example, lighting levels of 500 lux and a UGR of 19 is recommended in offices while industrial areas intended for coarse work a UGR of 28 can tolerated. In good lighting practice, attention is given by lighting designers to the correct amount of uplight, that is, light exiting from the luminaire towards the ceiling, which prevents a gloomy "dark cave" effect. Attention is also given to the cut-off angle of the luminaire, usually provided by shielding elements, such that high intensity rays are not emitted at an angle where they enter the occupant's eye during normal activity. A correctly designed luminaire for indoor lighting may provide 30% uplight and 70% downlight in the angles from the nadir 0 to 60 degrees and then again 135 to 170 degrees. A governing equation in lighting and used in "reverse luminaire design" of the present invention is the cosine law or Lambert's law, Equation 1:

$$E = I \cos\theta / D^2$$

Where: E=Illuminance in lux or footcandles, I=Luminous intensity in candles, D=Distance between the source and the point of calculation in meters or feet, θ=Angle of light incidence with illuminated surface

Another useful equation used in fixture analysis to avoid glare producing designs yields the level of discomfort on the DeBoer scale. The DeBoer rating scale (1-9) describes the level of discomfort where: 1=Unbearable, 3=Disturbing, 5=Just acceptable, 7=Satisfactory, and 9=Just noticeable. The allowable level is dependent on the application. A surgeon performing an operation may be very sensitive to glare while a chlorophyll producing plant is not. The equation to determine the rating is Equation 2:

$$W = 5.0 - 2.0 \text{ LOG } [E_i/(0.003)(1+\text{SQRT}(La/0.04))(\varphi_i)^{\wedge}0.46]$$

where: W=glare sensation on a scale of 1 to 9, La=adaptation luminance (cd/m 2), E_i=illumination directed at observer's eyes from the i-th source (lux), φ_i=glare angle of the i-th source (minutes of arc) from the observer's line of sight.

Using these equations and correct lighting practice covering preferred angles of lighting for visual tasks, it is possible to design from the specific application's illumination requirements the spatial light intensity distribution and yet avoid manufacturing a glare producing luminaire.

The present invention generally relates to an improved illuminator for use both in general and specialty lighting. The term general lighting includes use in living spaces such as lighting in industrial, commercial, residential and transportation vehicle applications. By specialty lighting we mean emergency lighting activated during power failures, fires or smoke accumulations in buildings, microscope, stage illuminators, billboard front-lighting, hazardous and difficult access location lighting, backlighting for signs, agricultural lighting etc.

Energy Efficiency and Costs. In an example to illustrate the advantages of an energy efficient lighting solution, the total cost of lighting a typical 300 foot by 300-foot retail facility at 1000 lux over a 10 year period using state of the art (2002) HID luminaires is assessed. Including equipment, installation and maintenance cost the total bill is over one million dollars. Approximately 80% of this is in energy costs. The commodity being purchased is lighting, the major lifecycle cost is electricity. To cut down on costs and also conserve energy it desirable to maximize the use of light generated. A Japanese survey of office luminaires (Japan Lighting Information Services-Seminar-Save Energy of Office Lighting-Loss of light in luminaire-.htm) shows LF efficiencies (light that exits the fixture vs. the light produced by the lamp) in an open office fluorescent luminaire without anti-glare louvers to be 84% while one equipped with louvers is only 52% efficient. The "utilization factor" (which equals the light flux which arrives at a work site (e.g. upper surface of a desk) divided by the sum of all light flux of the lamp) is 74% for an open fixture and only 50% for louvered version. This however, is still not what the customer is paying for. The customer is after the best lighting solution at minimal energy cost. Chances are, as experienced lighting designers know, that the light intensity, even in a good lighting design, is still not evenly distributed over the work surfaces. While care is taken in the lighting design computer runs not to fall below the minimum illumination intensity at any point in the room, there are non-trivial excesses at some points in the lighting layout design. This excess light, wasted energy as far as the customer is concerned, probably accounts for another 10% loss. While a fluorescent may appear to be a superior and very efficient light source at 80 lumen per watt vs. 30 lumen per watt for LEDs this is not actually the case, in actuality 60% of the fluorescent LF's light is wasted. Thus, in terms of energy use, a properly designed LED luminaire can be, with the proper luminaire design of the present invention, as effective lumen per lumen as any discharge light source in illuminating living areas.

Expressed in terms of the above background and nomenclature, it is the goal of this disclosure to teach how to construct a luminaire which will radiate photons where needed, exactly in the correct amounts to accomplish visual

tasks and/or create an atmosphere. The controlled radiation of light into a living space with a specific spatial intensity distribution also having optimal spectral characteristics for the seeing tasks at hand is provided by the present invention. Each visual task application has its own correct lighting solution with optimal light intensities, light color emanating at angles which will not cause glare that interferes with vision or causes discomfort. Tasks in living spaces vary with time so it is another objective of the present invention is to provide the optimal lighting solution in "real time" (at that specific moment in time).

As a light source of ever increasing choice, LEDs have been packaged in numerous forms and used in lighting applications. Special control circuits have been developed to take advantage of the variability offered by the new light source and are today being offered as a solution to specific applications. In general, however the design process has not zeroed in on providing the correct lighting solution. A number of LED illumination devices create "white" light by combining two or more LEDs of various wavelengths. White LEDs are also made using phosphors. The goal has not been to vary this color spectrum in real time to coordinate with the usage of the living space. The term "white" light is loosely interpreted to cover a range of illuminating light having spectral light distributions acceptable to the user for that application. HPS's yellow light has even been called white by some and the term is exclusive only of almost monochromatic sources such as LEDs and LPS lamps. The terms light spectrum, spectra, spectrum, spectral and color are used to refer to the relative spectral power distribution of the light source.

Description of the Prior Art

In prior art illuminating devices, a universal light source such as an incandescent or fluorescent lamp emits light in many directions up to a 360 degree light distribution where in practice only a limited angular light distribution is needed in order for people to carry out visual tasks. So as to control the light distribution to certain angles, reflectors and refractors are used to redirect the light where it is needed. A great deal of light is wasted in the inherent inefficiencies in redirecting the light and shielding the glare causing light sources. In addition, the actual placement of the light rays where needed, but not beyond, is often inexact and wasteful.

In addition, it necessary to have a wide variety of lighting fixtures each with dedicated optics and even then, there is much wasted light or insufficient lighting in the area covered by the luminaire. In addition, the light intensity and color spectrum of the luminaire is fixed while the visual tasks going on in the space are changing all the time. Usually, there is no provision for either detecting the changes going on in the living space nor is the lighting fixture equipped with apparatus to effect the necessary changes in the lighting. In addition, individuals often have their personal lighting preferences as to the color and intensity of the lighting. Prior art lighting fixtures have no provision for the localized provision of preferred lighting to individuals.

A prior art LED light strip consists of circuitry including a plurality of LEDs mounted on a substrate and connected to electrical conductors. The circuitry is sometimes encased within a tube like, partially transparent protective sheathing and connected to a power source for selective LED illumination. Two examples of LED strip types are described in U.S. Pat. No. 5,130,909 to Gross, entitled Emergency Lighting Strip and U.S. Pat. No. 4,597,033 to Meggs et al., entitled Flexible Elongated Lighting System. Such strips are utilized in a variety of indoor and outdoor configurations such as emergency pathway markers, exit door indicators and ornamental lighting arrangements. The LEDs are being used as outline markers where the lighting strips are the object to be seen. It is not the purpose of the lighting strips to project light on other objects to make them visible. In other applications, where lighting distributed evenly along an area is required, these strips are placed at an edge. No attempt is made at obtaining an even illumination outward from the edge to the area perpendicular to the long dimension.

LED lamps and ballast systems can reduce maintenance costs due to an average rated life of 100,000 hours. This is five to eight times the typical service life of conventional fluorescent and metal halide lamps. The present system is especially well suited for applications where relamping is difficult or expensive.

U.S. Pat. No. 6,346,777 issued Feb. 12, 2002 to Kim teaches an illuminating lamp assembly. An LED lamp apparatus comprises a plurality of LED lamps including at least one LED chip mounted on a Printed Circuit Board (PCB), on which a driver circuit and/or a control circuit are provided in a printed circuit pattern to drive and/or control the LED chip. The device is independent of the lighting application and is simply a lamp not a lamp and fixture combination.

U.S. Pat. No. 5,018,290 issued May 28, 1991 to Kozek et al. Teaches an exit sign with a plurality of low voltage incandescent lamps mounted on a PCB to provide illumination from within a housing. There is no combination of different light source characteristics to build a new combined light source characteristic and this is a lamp replacement not a LF fit for general illumination.

U.S. Pat. No. 5,577,832 to Lodhie one of the originators of the use of LEDs for illumination, describes a multilayer LED assembly which is used as a replacement light for equipment used in manufacturing environments. On each layer of the multi-layer assembly, there are multiple LEDs which are mounted perpendicular to a base. The base is used to provide electrical and mechanical connection to a socket. The LED assembly may utilize multiple layers of LEDs, with each layer itself having multiple LEDs. The LEDs in each layer are mounted in a direction perpendicular to the base which results in light emanating in a direction perpendicular to the base. The LED assembly is used as a replacement lamp for equipment used in manufacturing environments. There is no attempt to match the light distribution to the task at hand.

U.S. Pat. No. 6,379,022 issued Apr. 30, 2002 to Amerson, et al. titled Auxiliary illuminating device having adjustable color temperature, describes an auxiliary illuminating device that has a least two preset ratios of light adjustable color temperature. The color temperature is adjusted by varying the light output at least two independently adjustable light sources. The light source is an array of at least 2 colors. The light source typically uses at least one set of LED's. The application specifically relates to use in producing correct lighting for photography but does not relate to general illumination so that its control equipment does not correlate the overall illuminance level to the color temperature over the range of illumination nor does its control equipment integrate the aiming function for correct light distribution. Essentially the auxiliary illuminating device is a lamp replacement for a photographic flash lamp.

U.S. Pat. No. 6,340,868, Illumination components, discloses a current control for an LED lighting assembly, where each current-controlled unit is uniquely addressable and capable of receiving illumination color information on a

computer lighting network. The teachings of the above patent are incorporated herein by reference. Although this patent discloses how to construct controllable illumination light systems this patent does not relate to the concept of control within the parameters of accurate light distribution and correct lighting practice.

In U.S. Pat. No. 6,498,440 Stam, et al. incorporated herein by reference, describes a lamp assembly incorporating optical feedback to produce an illuminator assembly that is capable of utilizing a plurality of light sources to produce a desired resultant hue. The assembly includes a processor, a memory, a plurality of light sources and a detector. The memory is coupled to the processor and stores data and information. Each of the plurality of light sources are coupled to the processor and produce a different color. The processor is capable of independently controlling the intensity of each light source so as to produce a desired resultant hue. The detector is also coupled to the processor. The detector provides the processor with information which the processor utilizes in determining how to adjust the intensity of each of the light sources to provide the desired resultant hue.

In an earlier patent U.S. Pat. No. 5,803,579 titled: Illuminator assembly incorporating LEDs, by Turnbull, incorporated herein by reference, the different color LEDs light output is coincident in such a manner that this overlapped and mixed illumination forms a metameric white color and has sufficient intensity and color rendering qualities to be an effective illuminator. Electronic circuits for control of the independent light sources consist of microprocessor controlled adjustable current sources.

United States Patent Application 20020130326 issued to Tamura et al., incorporated herein by reference, describes a lighting device that includes a plurality of LEDs arranged in an at least two-dimensionally dispersed manner; a transparent resin layer that covers the plurality of LEDs in an integrated form; a photo-detecting unit that detects an intensity of light emitted from the plurality of LEDs using a photodetector and a power supply circuit unit that controls driving of the plurality of LEDs based on a detection output from the photo-detecting unit. The purpose is to have a predetermined balance of light intensities of the colors according to an output detected as to each color by the photo-detecting unit. This device does not integrally cover the light distribution function within and does not correlate the lighting spectrum with the light intensity. It also does not provide a method to handle color shift over the lifetime of the illuminating device.

In U.S. Pat. No. 6,528,954 a light bulb is provided which may include a housing, an illumination source, disposed in the housing, and a processor, disposed in the housing, for controlling the illumination source. The housing may be configured to fit a conventional light fixture. The processor may control the intensity or the color of the illumination source. The housing may also house a transmitter and/or receiver. Although this device includes the desirable communications control aspect, this device does not relate to a multi-light source capability which allows for the smooth variation lighting and its even distribution.

In the prior-art approach, the LED manufacture and the power supply manufacture are separate units. Typically, one power supply is good for a certain number of LEDs. This is similar to the historical lamp and ballast segregation that came about probably because one manufacturer was working with glass and the other with copper. Electronic light sources are semiconductor components as are the power supply components. A unique opportunity for integration exists in solid-state luminaire design which has not being taken advantage of.

In many energy conserving multi resident stairwell lighting systems the lights are typically activated by pressing a button in the hallway or in each apartment. This requires special wiring between the switches and the central controller. In many other stairwells and hallways, the lighting is always left on wasting energy. With long life LED lamps, a low energy distributed lighting solution could always be on for orientation purposes and would only turn on to full output when activity levels require the lights turning on, using integral optoelectronic motion detectors.

A home lighting fixture is often left on at full power when really only lighting for orientation purposes is required. A light switch on the wall is provided and sometimes this has a dimmer option. An electronic power supply with programmable electronic controller with communication over a dedicated data line or alternately over the power line or alternately wireless is also possible in present art such as with the DALI (Digital Addressable Lighting Interface) protocol. With digital signals, power supplies become individually addressable compared to analog systems where only circuits are addressable. Additionally, DALI allows for bi-directional communication between the power supply and control. DALI also brings the capability of broadcast messaging to ballasts. With DALI or any other protocol much more than dimming can be effected. Control of spectrum, occupancy sensor controls and specific spatial intensity distributions can be modified. However, the present-day lamp or fixture is not designed to fully and efficiently take advantage of these new control capabilities.

In United States Patent Application 20100302779 by Chemel titled Fixture with Replaceable Light Bars he describes an intelligent LED-based lighting system. The LED based lighting systems may include fixtures with one or more of rotatable LED light bars, integrated sensors, onboard intelligence to receive signals from the LED light bars and control the LED light bars. In this system while an adjustable system of moving bars is illustrated so that the LED luminaire can retrofit a variety of older discharge lamp-based luminaires, advantage has not been taken of the multiplicity of light sources to obtain a superior light distribution lighting solution that is now obtainable with multiple sources.

Spero in United States Patent Application 20040105264 describes the design of a multiple light source system using unique placements of the LEDs on the structure of a lighting fixture to generate an application specific light distribution pattern capable of providing recommended illuminance levels. The lighting fixture has means for being affixed within a living space to be illuminated in a unique orientation in relation to the surfaces therein. Subsequently, the lighting fixture is designed by positioning LED light sources thereon that emanate light in direction and intensity as required by the lighting application. The geometric layout is determined by using knowledge of the distances and angles from the light sources to the living-space surfaces as dictated by the inverse square law and Lambert's Cosine Law of Incidence. The combination of the unique placement of the LEDs on the lighting fixture and the unique orientation of the fixture in the living space results in the predetermined illuminance being obtained on the room surfaces. A problem with this technique can arise in non-standard illumination instances which may be the majority of lighting applications. For example, in industrial plant lighting, such as in open chemical processing facilities or where there are desks, shelves,

machinery or other elements requiring an unpredictable light distribution. Much energy is wasted in these facilities with the wasted light often contributing to light pollution.

In another embodiment Spero describes a solution to this problem where an overabundance of LEDs are deployed on the fixture structure giving it the ability to illuminate in all directions at required intensities. The controller of the LEDs is coupled to a camera which analyzes surfaces and usage within the living space and adjusts the lighting accordingly. While the design is highly flexible it requires an over capacity of LEDs and the cost of driver and light sources would be high.

People need light for the performance of visual tasks, its aesthetic value or security. Light generated but not used by people is wasted energy, money and causes air and light pollution. Standard lighting fixtures, even those that are somewhat area based, such as a low bay or bedroom luminaire, because of the different object and usages within the area, either provide too much light and are wasteful or provide insufficient lighting inhibiting visual performance. Therefore, it would be beneficial to have a lighting fixture that is further configurable to meet the demands of the actual lighting application where it has been installed. In addition, it would be beneficial if the lighting fixture was responsive in real time to the lighting needs at that moment. It is no longer necessary to have fixtures providing illumination where there is nothing to be seen.

Thus, there is a need for a lighting fixture having provision for the differentiation over space and time of the light's intensity and color that could be set-up in the field and/or adjusted in real-time to the changing lighting requirements. Such an exigency-based fixture would provide correct illuminance in terms of chromaticity, homogeneous or aesthetic lighting generally and task lighting locally for the visual tasks at hand.

Prior art lighting practice utilizes an apparatus termed a luminaire or Lighting Fixture to provide illumination to indoor and outdoor living spaces, vehicles machinery etc. for the performance of various visual tasks. A luminaire provides features other than just light which may include light distribution, shielding, man-machine-interfaces such as on/off switches, connection to power mains, apparatus for affixation to construction elements and aesthetics. A typical prior art luminaire is comprised of: a replaceable lamp, a lamp holder, wiring, optical control elements such as a reflectors and refractors, fasteners and brackets. In addition, if the lamp has a negative resistance characteristic, then the luminaire includes power control elements such as a ballast. If a light control system is employed also included are elements including relays, logic controllers and communication devices which may be part of an electronic ballast design. All of these elements packaged together constitute a luminaire. In typical present-day luminaire (lighting fixture) practice, a lamp with a mostly radially uniform spatial light distribution is placed within an optical assembly consisting of a reflector and or refractor for the purpose of having the light exit the luminaire in the desired direction and preferred distribution pattern. This is a process that involves cost and inefficiencies in redirecting the light.

Recently solid-state light sources have evolved from indicator lamps into illumination sources. The present art approach is to package these new lamp types into luminaires of the old lamp type with some minor adjustments. This was the case when fluorescents replaced incandescents and when HID replaced fluorescents. The question arises, is this really the best solution as far as functionality and construction are concerned. The question is especially cogent when the fact that solid state light sources are electronic devices with high reliability, long lifetimes and are capable of rapid change over a very wide operating range.

Examples of the inflexible prior-art approach based on today's designs include: lighting is often provided in rooms where daylight contributes significantly to the overall lighting level or in areas near the window but the lighting system is not flexible enough spatially to take advantage of the daylight contribution and reduce power; or the lighting is always on at maximum power irrespective of whether or not there is activity in the room to justify the lighting level.

Even when external dimming controls are provided to the lighting fixture, the color quality of the lighting is deleteriously affected. At a lower lighting level, a warmer color temperature is generally required, and the luminaire lamp color is not adjustable.

Lighting systems are generally based around a lamp source and lighting application. When a new lamp source arrives generally they are placed into present-day lighting luminaire designs which are not optimal for the new light source. LEDs are a light source which have a number of advantages due to relatively long-life expectancy. In the future it is also expected that LEDs will have conversion efficiencies equivalent to those of discharge lamps. Presently however, the high cost of lumen per watt appears to make LEDs uneconomical for most lighting applications. A few applications of which step, stairwell, pathway and emergency lighting are examples require low lighting levels to begin with and thus present at this time a feasible application. An LED light source is well adapted to a number of additional applications. Very often in these additional applications the areas over which the lighting is to be provided are large and bringing electric power to the luminaire is a significant safety and cost consideration. An inherently low voltage light source such as an LED is suitable for use with safe 12 or 24 volt of a distributed power system with low current demands. The control of the light distribution, especially the beam cut-off necessary at low light levels to prevent discomfort, is well suited to the high directionality of the small LED light source. Maintenance of prior-art luminaires in outdoor applications and the requirement for watertight resealing increases fixture cost and complexity. Robustness of luminaires is another requirement as they located on ground level endangered by passersby contact or vandalism.

In prior art lighting fixture construction, the lamp, reflector, socket and ballast are separate units. Foremost, the lamp must be replaceable and thus access provided, because the lamp lifetime is less than other components in the fixture. The reflector is large, to envelope the light source and provide ray control, and is manufactured of special, highly reflective, material. The power-conditioning device such as a core and coil ballast or more recently electronic power transistor components differs again from the glass lamp, reflector and fixture material. The dissimilarity of the manufacturing technologies, operating lifetimes and materials results in a multi-component fixture assembly held together by fasteners which don't lend themselves to mass production and the luminaires are not factory sealed for life.

Objectives of the Invention

The present invention provides a unique approach to solid-state illuminating devices that is a departure from conventional prior art LED lighting practice. Prior-Art LED lighting technology manufacturers have been taking LED junctions and packaging them in ever more-powerful con-

figurations to carry out the function of lamps. These LED lamps are teamed with reflectors and/or refractors similar to the techniques practiced with standard lamps or put on strips which is just another way of distributing the light over the area to be illuminated. This invention comprises a different approach which is to provide the end user with the most correct lighting solution not a new technology lamp to replace the old one. The present invention comprises a novel multi-light source approach to the design and construction of solid-state lighting fixtures (vs. solid-state lamps), which is termed a "Digital Lighting Fixture", due to the control of individual lighting element "digits" to provide the "correct" lighting solution for the situation at hand.

The invention embraces LED-illuminating devices covering a wide scope of applications including a room light and step light design as well as the general method for designing solid state luminaires from ground up from indoor to outdoor use in residences, factories, stores stadiums and streets. The general concept allows anyone to build a lighting fixture from the ground up, tailor made to the final application rather than building a fixture around a common lamp. This is because it difficult to control the high temperature processes of incandescent and discharge lamps. In addition, it takes a tremendous amount of investment in tooling to manufacture an incandescent, fluorescent or HID lamp. Electronic components on the other hand are made of large quantities of discrete components which are masked or robotically placed on to substrates. These smaller building blocks can then be easily configured per specific applications.

This disclosure also teaches that when it comes to solid-state lighting big is not necessarily better. The approach of LED manufacturers trying to get into the lighting business by attempting to replicate the effect of present day lamps has been to make large, high current capacity, high lumen output electroluminescent junctions having marginally acceptable lighting characteristics. Lumileds Luxeon® DS25 Emitter running at 350 mA is an example of such an approach. In a few years manufacturers have raised currents from 50 mA to above 500 mA, at the time of this writing. These advances are certainly favorable at reducing costs and making LEDs a practical light source but attempting to get 1000 lumen (equivalent to a 60 W incandescent lamp) is not necessarily the best path to take, especially if it comes at the price of light conversion or distribution efficiency. In contrast to a prior art, single large, lamp replacement like light source, the present invention provides multiple, small sized sources of differing characteristics such that the effect of the whole is greater than the sum of the individual parts. The determining size factor then becomes when is there a sufficient progression of values varying by minute degrees or continuum so as be non-discernable or irrelevant to the user. That is, LEDs are generally of a single wavelength (color, frequency), have small optics close in to the individual light sources since they operate coolly, and have stable conversion efficiency over a wide range of currents and light output. The added controllability offered by breaking the total light output up into discrete ("digital") specifically aimable and dimmable elements which can be addressed by control electronics to effect intensity, spectrum and spatial distribution of intensity and spectrum, yields a lighting fixture (vs. lamp) of unparalleled performance. Unique to this patent is the approach. It is the approach of a lighting manufacturer who provides lighting solutions versus that of a lamp manufacturer who produces a generic lamp.

The advance over prior art is a solid-state light source with increased: 1. Efficiency—more effective lumen per watt electricity. 2. Durability—physical strength, life expectancy, lumen maintenance and spectral stability. 3. Lighting quality—as related to visual comfort and "atmosphere". 4. Functionality—ability to control the light placement, intensity and color temperature and do so as needed. 5. Energy savings 6. Lower overall lifecycle cost

Integrating the light source with power conditioning electronics, control circuitry and sensors gives additional cost benefits and functionality including: 1. Mass production capability 2. Sealed-for-life fixture 3. Exact optical performance less spill light 4. Compact design 5. Feedback control and recalibrated color consistency over the device lifetime 6. Real-time lighting needs adaptability.

Therefore, it would be advantageous to have a luminaire that require no maintenance, has smoothly controllable light output in terms of intensity, spectra, spatial distribution, is robust, mass-producible as a single unit, factory sealed against the elements, is self-calibrating over its lifetime, is adaptable to changing requirements, works on high or low voltage, has an affixation apparatus and is aesthetic.

Further Objectives of the Invention

The objectives of the present invention are (among others) to overcome the deficiencies in the prior art and effect the following: Light is generated only when, where and in the proper amount and color that can best be used by people or is their personal preference. This will save wasted energy, money and air and light pollution while increasing visual performance and comfort. An exigency-based lighting fixture is presented that provides correct illuminance in terms of chromaticity, homogeneous or aesthetic lighting generally and task lighting locally for the visual tasks at hand while preserving high visual comfort.

A number of unique illuminating device embodiments are achievable using the basic elements presented above. A few examples presented in the disclosure include: (1) an industrial lighting fixture for use in chemical and process plants where lighting that normally spills out of the existing structure as wasted light, is not produced to begin with; (2) a bedroom luminaire where normal activity and night-light lighting levels are provided as well as the ability to provide individualized lighting to each person; (3) Living room lighting with provision of modes for typical uses such as television viewing, reading with the provision of radiant spot heating based on the users unique location and usage at that instant in time; (4) A therapeutic luminaire designed to use illumination and irradiation on persons to alter biological disorders or schedule sleep or awakening; (5) a luminaire for emergency and security forces having a non-readiness situation intensity and chromacity and second high-readiness situation setting of a unique intensity and/or chromacity, where the unique chromacity does not damage the biological visual purple pigment of the retina that is responsible for enabling night vision. It thus eliminates the time these security forces would need to adjust from normal lighting to low-light night vision conditions; (6) a restaurant luminaire which illuminates foods and/or people in their best light while providing for the correct level and chromacity of ambient lighting for generating the optimal dining atmosphere; (7) A general luminaire which the end user configures themselves in situ to best suit their desired lighting preferences. The field adjusted luminaire comes with the lighting elements and their power supplies but the user re-arranges in particular directions and sets their light output levels and/or chromacity to obtain the preferred output; (8) A do it yourself modular lighting fixture which is a structure

capable of receiving light sources over its surface where the user chooses the light source with its chromacity and intensity level. The user builds up the light distribution pattern on their own and connects the sources to the integral modular power supply; (9) A single light engine device for a room or outdoor location with concentrated light output capable of being beamed distances to reflectors or refractors which redirect the light to be more optimally used in a localized area.

The overall objective of these exemplary embodiments is the disclosure of an exigency-based lighting fixture that provides correct or user preferred illuminance in terms of chromaticity, homogeneity, aesthetic considerations over a general area and/or task lighting provided in a small area for the visual tasks at hand. Providing illumination only where, how and when it is needed to efficiently carry out visual tasks minimizes wasted light thus minimizing energy use for lighting. To achieve this efficiency goal there is a need for a lighting fixture having provision for 1) the differentiation over space and time of its light intensity and color 2) that can be set-up in the field and/or 3) adjusted in real-time to changing lighting requirements.

While these objectives should not be understood to limit the teachings of the present invention, in general these objectives are achieved in part or in whole by the disclosed invention that is presented in the following sections. One skilled in the art will no doubt be able to select aspects of the present invention as disclosed to affect any combination of the objectives described above.

SUMMARY

A lighting device incorporates one or more discrete light sources and their ancillary optical and electrical control equipment in an integrated illuminating element. The overall lighting effect is the result of the combination of these multiple sources, detector and control components operating together. Preferably, the power conditioning circuitry, light sources, logic control circuitry, sensors and optical elements are packaged together in one integral device. The system contrives a lighting device which replaces the present day multi-component lighting fixtures or luminaires including: the lamp; optical light control element/s such as reflector, refractor and shade; power conditioning devices such as a ballast; control equipment such as switch, dimmer, and timer. Detectors, emitters and sensors for light intensity, spectrum, temperature etc. such as photodiodes, photocells thermocouples etc. are provided. These provide data input to the controller, allow feedback and enable recalibration. An additional apparatus that conducts electric power along length, as electrical wiring, may be added to the system to provide further unitization. The integral lighting element is packaged in the shape of a globe, hemisphere, disc or strip and is designed to quick connect to the electric power carrying conductors. Provision is made for mechanical affixation to a structural surface. In the present concept over the life time of the fixture there is no lamp replacement only fixture replacement. It's assumed that after 100,000 hours it is time to change the fixture.

The method of creating a luminaire adapted to the usage and surroundings in which the luminaire will be integrated is disclosed. The process includes determining: the correct lighting practice for the application; the surroundings; the selection and placement of light sources and their integration with the mechanical support and; electronic control elements to realize the objective.

The present invention also relates to lighting fixtures comprised of many directional light sources that are mounted with different aimings so as to correctly illuminate an area. The LED light sources are moveable so that they can be adjusted to best illuminate the area where the luminaire has actually been installed. In addition, they may be controllable by a microprocessor as to the light intensity and color so as to best assist people to see what they are doing at that moment, be it reading a book, watching TV or assembling an automobile. The lighting fixture is equipped with a "smart" camera (similar to a cell phone's processor controlled digital camera) which inputs data on the lighting, occupants and current conditions within the room. The result of this added sophistication is that electricity is spent on generating only useful light. The energy savings greatly reduces electricity costs and environmental impact.

The present invention more specifically relates to lighting fixtures whose spatial light distribution and/or spectral power distribution is capable of being adapted, either manually or automatically, to provide the illumination needed in that specific surrounding and at that specific time. The Field Adjustable Multiple-Light-Source Luminaire, FAML, is thus a universal product that can be tailored onsite so as to provide design illuminance and color spectrum to the relevant surfaces in the specific lighting installation. Thus, a preferred embodiment of the invention is a lighting fixture comprised of many light sources which can be separately aimed and powered so as to illuminate areas or objects in a room or outdoors in a most correct, efficient and comfortable manner.

To affect this directional lighting versatility, in a preferred embodiment the luminaire is comprised of many directional light sources that can be re-positioned so as to illuminate in different directions. The light sources at a particular aiming may all be one color, say white or may be of different colors which when combined together yield a different colored light beam. Altering the radiated power of one color light source versus the other allows for the creation of light in a myriad of colors. The luminaire has some light sources at the same aiming and others at different aimings and may come in a standard configuration for the general type of lighting application from the factory. Upon installation, if the factory preset lighting distribution does not fit the actual surroundings, the installer will customize the configuration by adjusting the light source aimings and light intensity output such that the correct amount of light is supplied to where it is needed while not at all or minimally illuminating areas where it is not needed. The installer will also make provision for the existence of other lighting fixture in the same or adjacent areas. When light is provided at higher angles and glare would result from the LED light source being visible, the light is not wasted by covering it with a shade or passing the light through a diffuser thereby losing the directionality and light flux due to absorption. Instead taking advantage of the small étendue of the light source, an optical spreader is used to increase the area from where the light is exiting thus lowering the luminous exitance while maintaining directionality.

To effect the provision of lighting that is in concert with the actual illumination needs at a given time, in an embodiment of the FAML, a camera serves as a sensor capable of detecting light, color and contents of the living space. The fixture is equipped with a logical controller. Using computer vision technology to recognize people, objects and surroundings the lighting fixture can provide the lighting requirements needed in the room at that moment in time. The computer vision system has been taught to recognize dif-

ferent visual tasks such as an individual operating a machine, reading a book or watching TV. The logical controller has instruction sets as to what color lighting at what intensity is preferable for that specific visual task. Thus if no one is in the room the lighting is off or a dimmed, aesthetic lighting is provided for the good feeling of those looking in. When people enter the room, immediately general room lighting is turned on and following that, specific task lighting is provided and adjusted to the right level and color based on where they are in the room and what they are doing.

An automatic embodiment of the FAML would include motion control elements for the light sources. Coupled with the camera and logical controller, the light distribution is altered automatically as required by changes in the physical surroundings, people or environment. In a similar fashion to how a preprogrammed moving head stage light follows the performer about the stage the FAML logical controller will automatically locate the person in the room and provide locally the lighting needed for the performance of visual tasks. To save energy, the rest of the room will then be illuminated at a lower, yet comfortable lighting level.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** represents a block diagram of the elements making up a Digital Lighting Fixture system.

FIG. **2**A is prior-art design and FIG. **2**B an illustration of a preferred embodiment of this invention of a retrofit LED lamp illuminator while FIG. **2**C is a side view of an embodiment of this invention using a PCB provided with standard 5 mm hole-through LEDs.

FIG. **3**A and FIG. **3**B illustrate a preferred embodiment of a decorative LED outdoor wall sconce juxtaposed with a prior-art design.

FIG. **4** is an illustration of a Surface or Railing Mounted Digital Lighting Fixture.

FIG. **5** is a Surface or Railing Mounted Distributed Digital Lighting Fixture.

FIG. **6** is an Asymmetric Light Source made of Directional Chip Facets.

FIG. **7** illustrates an application employing the Discrete Unit Step Light.

FIG. **8** illustrates an application using the LED based Distributed Step Light Fixture.

FIG. **9** is a path lighting application using an LED Stake-Top Path Light.

FIG. **10** is the Illuminating Engineering Society Preferred Color Temperature vs. Intensity Correlation.

FIG. **11** depicts an integrated digital lighting fixture using discrete solid-state light source arrays deployed angularly about the geometric volume.

FIG. **12** is a universal luminaire embodiment using an adaptive digital lighting fixture which is programmed to illuminate the area as is needed.

FIGS. **13**A through **13**C depict a streetlight fixture designed according to the teachings of this invention.

FIG. **14** is a flowchart of a typical design procedure for a multi-source lighting fixture of the present disclosure

FIG. **15** shows a multiple light-source headlamp capable of optimally carrying out the diverse illumination functions used in driving under various environmental conditions and surroundings.

FIG. **16** is an illustration of an anti-glare system using the multiple light source headlamp.

FIG. **17** a representative Electronic Power Supply Unit for Surface or Railing Mounted Luminaire.

FIG. **18**A is a perspective view of a configurable LED luminaire comprised of many light modules;

FIG. **18**B is a view of light module optical accessories;

FIG. **19** is a perspective view of a light guide;

FIG. **20**A and FIG. **20**B are perspective view of basic embodiments of the present invention;

FIG. **21** is a perspective view of a substantially linear embodiment of the present invention;

FIG. **22** is a block diagram of the elements comprising the present invention;

FIG. **23** is an exemplary flow chart for a computer program run to obtain the optimal illumination;

FIG. **24** is a perspective view of a universal lighting fixture structure with means for attaching light source and sensor elements mechanically and electrically;

FIG. **25**A and FIG. **25**B shows an embodiment where the light source arrays are mounted at the end of moveable rods;

FIG. **26** is a perspective view of a lighting fixture capable of producing both a differentiated spatial light intensity distribution as well as a spatially differentiated light spectrum distribution;

FIG. **27** is a perspective view of a field adjustable multiple light source lighting fixture;

FIG. **28**A and FIG. **28**B is a perspective view of satellite light source from the side and from the front respectively;

FIG. **29** depicts an adjustable luminaire in a lighting application;

FIG. **30** is a perspective view of a luminaire with a special night-light functionality;

FIG. **31** is a perspective view of an adjustable luminaire with added irradiation functionality;

FIG. **32** is a perspective view of an industrial lighting fixture for use in hazardous locations;

FIG. **33** is a process flow chart for a computer lighting fixture design program.

DETAILED DESCRIPTION

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.

The system is built around a "digital" light source. That is, the emanating lighting effect is the sum of the characteristics of a multiplicity of discretely controllable "digit" sources. The difference between the individual "digit" light sources and their summation manifests itself in the resultant light characteristic, be in its intensity, spatial intensity distribution, spectral energy content and spectral intensity distribution. All of these characteristics are also variable with time. A light source for this purpose may be electroluminescent such as a Light Emitting Diode (LED) junction, Organic Light Emitting Diode (OLED) or carbon-related field emission devices such as a nanotube-phosphor-combination, HID, fluorescent or even an incandescent source. While a one-source lamp will not have the flexibility to effect the most correct illumination characteristics, such as maintaining correct intensity and color temperature for the lighting task at hand over changing environmental conditions, two or more differentiated sources will have an increased operating

range. This flexibility is useful as for example in a multi-source luminaire with spatially differentiated dimming capability used in an office lighting application. In a normal day's operation, such as in a windowed room between peak daylight and nighttime hours, the intensity and color temperature of the light varies greatly over different portions of the room. The smooth variation possible with many light sources ("digits") vs. one light source offers superior flexibility in providing the actual lighting needs. Therefore, the illuminating device may be described as a "digital" light source or as a Multiple Solid-state Light Source (MSLS), comprising many "digits", SLSs, and essentially replaces the lamp of present-day luminaires.

As used herein, the term "light source", LED or "solid state light source" means any system that is capable of receiving an electrical signal and producing light in response to the signal. Thus, the term "light source" should be understood to include light emitting diodes of all types, light emitting polymers, semiconductor dies that produce or emanate light in response to current, organic LEDs, electroluminescent strips, and other such systems. Incandescent and discharge light sources are also included, and multiples of incandescent and discharge light sources also provide a digital luminaire. In an embodiment, a "light source" may refer to a single light emitting diode package including multiple semiconductor LED dies that are individually controlled.

The term "illuminate" should be understood to refer to the production of a wavelength of radiation by an illumination source. The term "color" should be understood to refer to any wavelength of radiation within a spectrum; that is, a "color," as used herein, should be understood to encompass wavelengths not only of the visible spectrum, but also wavelengths in the infrared and ultraviolet areas of the spectrum, and in other areas of the electromagnetic spectrum.

In designing a multi-light source luminaire, the minimum design criterion for intensity and spectrum differs for each application and is related to the end user who is the ultimate measuring instrument and economic consideration of the light provider. The regularity of the changes in effects is derived from the user's perception. It is generally accepted that the eye cannot discern changes in beam intensity that are smaller than a factor of two to ten and color temperature differences of 200 to 300K. Illumination intensity changes are discernable as a logarithmic function and depend on background illumination levels. For example, illuminating practice allows for hallway lighting to be 20% of room lighting due to rapid eye adaptation. However, the eye is very perceptive of intensity changes when comparing images such as in comparison of gray scales and thus lighting for an art lay-up room must be very even.

A further improvement is where the lamp and lighting fixture function are carried out in one device. In a typical present-day lighting fixture, a lamp with a symmetrical distribution in placed in a reflector to redirect the light, a requirement involving added cost of the reflector and performance inefficiencies. While PAR and other integral reflector lamps exist, they again have a symmetrical distribution in one of the axes and are large due to the high temperature of operation and requirement to distance reflective surfaces due to heat and large light source dimension consideration. Since the solid state or LED lamp is made of cool operating components which have a mechanical base (versus a 1000K gas discharge which is free floating) the LED allows for an integral small sized optical element near the power source. Where the terms optics or optical are mentioned herein, they refer to redirecting light rays through any of the known phenomenon including: reflection, refraction and diffraction. Typically, an LED will come packaged in an optical assembly consisting of a reflector and lens with 8° to 50° spreads being typical. A Surface Mount Device—SMD LED with no optics will still be limited to 180° due to its construction.

A power-conditioning device such as a ballast is required to operate efficient fluorescent and HID light sources but is separate there from in function and physical construction. In the MSLS the power source is electronic as is the control equipment and thus the electric power conditioning circuitry can be integrated with the light source circuitry and packaged as one on a PC board or integrated circuit manufactured in the same way of the same materials. Chip on board and chip on chip technologies are used as a packaging configuration for LED chips as well as power and logic control transistors and other components. Power transistors come packaged in plastic and so do LED junctions only that the LED package is light transmitting and can be formed into a lens. Transistors, molded in a transparent package together with LEDs, may be shielded from undesirably receiving illumination causing base photocurrent, by providing opaque "junction coat" over the transistor die, as is well known in the semiconductor industry. The packaging also lends itself to the same manufacturing methodology such as soldering elements onto a PC board. Both hole through and SMT configurations are presently available for most of the components. This combined unit of compatible, mass producible, apparatus, including the solid-state lamps, their optical assembly, electronic ballast gear and structural fixture equipment, provides a unique Digital Lighting Fixture (DLF) device.

In a preferred embodiment the DLF is provided with an onboard controller. The controller may be a computer board, embedded device, a Digital Signal Processor, etc. In general, the term "logical controller, controller or computer" can be broadly defined to encompass any device having control circuitry or a processor which executes instructions from a memory medium.

A further improvement is the reduction of all electronic and optical components to the chip level. That is, light-emitting junctions may be placed with power electronics in an integrated circuit. For example, combination GaAs LED-JFET technology may be used, the JFETs (junction FETs, acting as control devices for the LEDs. The carrier is made of materials and shaped to carry out optical and or heat transfer functions. Multiple light emitting junctions of similar or differing characteristics, a function of doping and diffusion, are placed with the control circuitry on chips. The VLSI techniques used in digital camera photodiode arrays containing millions of pixels is used to create arrays of light emitting diodes. Actually, reversing the current flow on some photodiodes will cause them to emit light. This is how OLEDs were discovered. OLEDs began in the lab as photovoltaic cells until by error they were driven in reverse. Alternately other die bonding techniques are used to create chip on chip assemblies as is known in the art. Sets of chips with similar or differing characteristics may be geometrically arranged to provide a specific light distribution and color mixing. The total envelope is then a combined lamp, power supply and lighting fixture "luminaire", and is positioned within the room to be illuminated at the design height and position to give a consistent and sufficient lighting to the area under its control. Cooling is effected using natural convection or for air currents from a cooling fan or fluidic cooling using natural or forced circulation.

On the chip and die level further magnitudes of manufacturing and packaging efficiency are realized. The integration can avail itself of other more compact packaging technologies such as chip on board and chip on chip. Assemblies with conductive and non-conductive diebonding using epoxies and eutectic solders used for a variety of semiconductor die types including ASIC's, MEM's, LED's and Sensor's. These may be used on a variety of substrate materials including FR4, Alumina, Metalized Ceramic, Carbon Fiber and Chip on Flex as single die or multiple die arrays for Chip scale packaging/CSP's. Conductors are attached to the dies via Aluminum and Gold wirebonding using both wedge bonding and ball bonding. The manufacture of Multi-chip modules/MCM or Chip scale packages/CSP are also possible and can be ceramic, laminate or PCB based. These assemblies can be single or multiple die assemblies with external components making it possible to manufacture all light, sensor, power and control components as a superior integrated device.

The present invention provides an illuminating device which serves as a replacement for the lamp, socket, reflector, electric power control gear, dimmer and mechanical structure of a present-day lighting fixture or luminaire. A semiconductor junction packaged integrally with light controlling components provides a Solid-State Light Source SLS and many together form an MSLS, which when combined with power conditioning, and optionally logic control, communications and affixing elements, provides a DLF. The basis of the invention is the use of a multitude of discrete light emitting sources ("digits") to generate light. The light control elements can be applied on a per junction basis or on a "white" color generating set grouping such as RGB or on a larger set which may be convenient for manufacturing or other color rendering considerations. The requirement for controllability is however, that the SLS output is definitive in relation to spectrum and spatial distribution.

The discrete light emitting elements by operating and not operating, at full power or at a fraction of, either partially or in unison, generate light with optimal intensity, spectral distribution, and spatial distribution of intensity and spectral distribution for the viewing task at hand. This is accomplished without recourse to separate (exterior to the DLF) reflectors to redirect the light, filters to alter color, shades to control glare or dimmers to control intensity. An example of light source used in a DLF would be an electroluminescent semi-conducting material an example of which is a LED. Such a source is characterized relative to a standard incandescent lamp by its small dimensions, low voltage, low current, monochromatic spectrum, high resistance to physical shock, high directionality of the light output, and at the present, relatively high cost. In addition, the intensity of the light output over a defined range is a function of the current and within limits may be varied by orders of magnitude without deleteriously affecting the efficiency or lifetime of the LED.

Although the light production of a typical 5 mm, 50 mA maximum rated, LED of between 1 to 2 lumen is much too low to be of any practical use for illumination, the combined output of a few to hundreds to thousands of LED's is quite significant. Higher current LEDs are now being introduced which operate at 350 mA and provide 20 to 30 lumen. This however, is still is highly impractical for use in lighting a room when compared to a 100 watt incandescent lamp of 1700 lumen. Based on progress to date it is expected that LEDs will reach comparative lumen per Watt efficiencies of 60 to 120 l/W as found in gaseous discharge lamps. This invention relates to technologies which are feasible at the present state of the art l/W as well as those which will become feasible in the future.

A "light bulb" of the present invention is comprised of a multitude of LED's where each LED or group of LEDs may be of the same or different wavelength, (color—where said wavelength may be mono or multi-chromatic), light output, spatial distribution and operating frequency (as when an alternating signal is used or it is multiplexed). The light from an LED or group of LEDs of red color operating with an LED of blue and green color impinging on an object would appear to the viewer as "white light". By varying the number and/or light power output of a specific color LED or group of LEDs relative to the others, a different intensity and color temperature of light with a "warm" or "cool" appearance may be effected. "White" LEDs can also be used in the invention alone or with other monochromatic LEDs. A white LED comprises an emitter in the blue spectrum covered with a phosphor which fluoresces in yellow such that the combined output appears white. White LEDs come in various angular light distribution patterns and color temperature variations. White LEDs can also be combined to vary intensity and spectrum. In the preferred embodiments, "white" LEDs are not used, as the use of phosphor adds unnecessary conversion inefficiencies and output degradation with time. The ability to correct for color shift over the DLF lifetime with white LEDs is limited. However, the present invention includes the use of white or other multi-spectrum light sources.

Presently the efficiency of many types of LED's (the chemical make-up of the junction differs between colors) is high relative to incandescent but low relative to discharge lamps. However, the theoretical efficiency is quite high, and the inefficiencies have to do with getting the light out between the junction and heat dissipation considerations. Expressed in lumens per watt LED's may produce up to 30 lumen/W versus 100 l/W for a discharge lamp and 18 l/W for an incandescent lamp. In the preferred embodiment, a highly efficient constant current power source is used to drive the LED's where the electronic circuit is a series connection of the discrete LED light sources. The open failure of an LED or series of LEDs which would interrupt the circuit is circumvented by the use of Zener diodes, placed such that the functionality of the lamp would not be seriously affected. The constant current power source has the advantage that different LEDs, of different forward voltage drops, from different manufacturing runs or chemical composition, may be operated together. Alternately, power circuits available in the literature for driving the LEDs are used as published in technical notes by manufactures such as Agilent®.

The life expectancy of an LED can be expected to be as high as 240,000 hours between failure. Due to light degradation over time average lifetime is normally rated at 100,000 hours. At best an incandescent's rated life may be 2,000 hours and that of a fluorescent, 20,000 hours. However, the LED operated in a circuit would have only the reliability of the circuit and MTBF divided by the number of series connected LED'S. A printed circuit board with the LED's alternately connected to separate circuits with redundant access to the power sources and with the use of Zener diodes every so many LED's to circumvent any failed sections could operate directly off of the 120/240V line. Any voltage AC or DC from 4V up to 480V is practical. The LED's of the hole—thru or SMT type would be soldered in place or the LED's connected leg to leg without using a PC board.

The LED's are mounted flat in rectangular patterns or in concentric circles or on or within holes situated on geo-